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Third Edition

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Technical Guidelines for Digitizing Archival Records for Electronic Access: Creation of Production Master Files – Raster Images *http://www.archives.gov/preservation/technical/guidelines.pdf*	Steven Puglia, Jeffrey Reed, and Erin Rhodes U.S. National Archives and Records Administration
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Acknowledgements

The history of this document, as listed on the preceding page, does not begin to give credit to all of the dedicated professionals that have contributed to the body of knowledge contained in this work. It would be impossible to list all of those who have contributed over the years.

However, we wish to acknowledge organizations that have given of their time and knowledge to create this, the third formal version of the *Federal Agencies Digital Guidelines Initiative (FADGI) Technical Guidelines*.

First and foremost, we thank the Library of Congress for providing the institutional support required to sustain FADGI which makes this effort possible. The Library of Congress has dedicated staff support for both the Still Imaging and Audio Video Working Groups and funds significant research efforts within the Library, as well as work with expert consultants outside the Library. This document could not have been produced without the support of the Library of Congress.

The National Archives and Records Administration was the initiator of Federal efforts to establish science-based technical guidelines for cultural heritage digitization. Long before the concept of a truly digital library was understood, National Archives staff worked to establish guidance which could allow digitized materials to become the core of what we now know as digital Libraries, Archives, and Museums.

In more recent times, the role of the International Organization for Standardization (ISO) in unifying guidance has ushered in an era where digitization programs worldwide can point to the same unified standards defined in ISO 19264-1:2021 Photography — Archiving systems — Imaging systems quality analysis — Part 1: Reflective originals. This was a significant achievement in the evolution of cultural heritage digitization, which opens up the possibility of a truly universal body of digital knowledge available to anyone, anywhere, and at any time. This is the work of the ISO/TC42 JWG 26 team, comprised of experts selected by national standards bodies worldwide. Some of these experts are official representatives of the nations they represent; others are independent experts serving without compensation.

FADGI Code of Ethics for the Still Image Working Group

The FADGI Still Image Working Group (http://www.digitizationguidelines.gov/still-image/) recognizes the code below, and this document follows this code.

FADGI Code of Ethics for Still Image Working Group -- January 24, 2020

The Federal Agency Digital Guideline Initiative (FADGI) Code of Ethics is a set of professional practices to guide imaging practitioners to create faithful reproductions of historic records held in the public trust. By conforming to the guidelines described by the FADGI program we believe values such as accuracy, integrity, and fidelity to the historic record are maintained. The cultural heritage community has a responsibility to produce digital images that look like the original records (textual, photograph, map, plan, etc.) and are a “reasonable reproduction” without enhancement. We encourage the use of digital technology to increase access to information without altering the fundamental nature of the historic record. We advocate for the dissemination of best practices to educate digital imaging practitioners. We recommend the inclusion of metadata or other documentation of the imaging process and any special processing performed on master digital objects.

The FADGI conformance program relies upon well-established practices, objective measurements, and quality assurance methods to create accurate imaging. The Program aims to reduce equipment variability, image artifacts, and other defects introduced by the scanning process and human subjectivity. To be considered FADGI compliant, a digital imaging process must implement a digital imaging conformance evaluation program, and compliance should be demonstrated in project documentation or metadata.

Digitized material should document the appearance of the original at the time of capture, not what it may once have looked like if restored to its original condition. Traditional techniques such as contrast and brightness adjustments, dodging, burning, spotting, etc., may be allowed on digital images. Certain digital enhancements should be avoided such as: Colorization, color restoration, digital infill, excessive cropping of the image area, over sharpening, de-saturation, blurring, removal of blemishes in the original such as stains, dust, or scratches, and other transformative image processing. The alteration of cultural heritage images such as the addition, removal, or changing of image details, including the addition, changing, or removing of individuals, subject matter, scenery, or the unrealistic changing of color or light are not acceptable. A successful imaging product should reflect the completeness, image quality (tonality and color), and reflect the intellectual context of the original material.

Other practices such as multi-spectral imaging, contrast adjustments, or other implementation of technical tools that increase access to information of faded text, burnt materials, mold damaged, image stitching or other physical limitations are acceptable, but should have metadata or other documentation that describes the image processing.

It is recommended that a well-defined set of metadata be included either in project documentation or file metadata that clearly describe any imaging procedures that fall out of the normal imaging processing that alters the appearance of the original such as:

- Colorization
- Composite image
- Stitching
- Sharpening
- False Color
- Cropping
- Enhancement
- Saturation
- Desaturation (turning color to grayscale)

We recognize that the set of practices described in the FADGI guidelines only cover a small range of professional responsibilities within the cultural heritage field. These practices are intended to compliment and inform other related code of ethics, and do not supersede applicable statutory, legal, or other code of practices.

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Chapter 1: Introduction

Guidelines are important tools for maintaining standards and consistency in many fields. Cultural heritage imaging is no different. Guidelines provide the framework by which standards can be successfully approached. With standards across the output of the whole field, it is easier to have a unified approach to imaging and makes it easier to discuss and resolve issues as a community. The purpose of this document is to present a common set of guidelines to cultural heritage and digitization professionals from a wide range of organizations and levels of experience.

The 2023 revision of the *Technical Guidelines for Digitizing Cultural Heritage Materials* builds on more than two decades of shared experience of the cultural heritage imaging community worldwide. The guidelines presented in this document are in full alignment with the work of the International Organization for Standardization ISO/TC42 JWG 26, responsible for the development of the ISO 19246 standard that defines the metrics for professional cultural heritage imaging worldwide.

These guidelines are intended to be used with appropriate imaging targets and software designed to provide analysis of the digital image, which is an essential element of a FADGI-conforming imaging program. There are a variety of imaging targets and analysis software available worldwide. Any of these may be incorporated into a FADGI-conforming process if they meet the ISO 19264 standard and can provide all of the analysis functions required by FADGI.

The U.S. Library of Congress is the host institution for FADGI, and all Guidance provided within this document has been validated by the Library's digitization program. We welcome professional visitors to visit our facilities on Capitol Hill.

1.1 Scope

These guidelines provide information on digitizing a wide range of materials. The evolving role of digitization in the preservation and presentation of knowledge has expanded our guidance in embracing that challenge. Some of these sections are a work in progress. These are labelled provisional.

These guidelines are informative, not prescriptive. Although they provide some practical advice, they are not meant to be a step-by-step manual for achieving results. No set of quality metrics or tests could ever replace the skill and experience of digitization professionals in evaluating the "goodness" of a digital representation of a physical item. However, the reverse is also true. Without a carefully designed and managed quality assurance program, no claim of FADGI conformance can be made.

The guidelines presented in this document provide a technical foundation for a FADGI-conforming digitization program, but do not exclude the adoption of alternate approaches that achieve conformance with the ISO 19264 standard.

The intended audience for these guidelines is cultural heritage digital imaging professionals and those who will be planning, managing and approving digitization projects. For those working on digital image capture and quality control, a foundation in photography and digital imaging is essential. Cultural Heritage digitization is a specialization within the imaging field that requires specific skills and experience. The FADGI Still Image Working Group has compiled these specific recommendations and best practices as they are practiced at participating institutions. Implementation of these recommendations must be managed by personnel with appropriate experience or in consultation with institutions or experts experienced in the FADGI digitization process.

1.2 Revisions

These guidelines reflect the current best practices within FADGI participating institutions and the world community of cultural heritage imaging professionals. These will change as technology, expectations, and applications for digital content evolve. We welcome your comments and suggestions at fadgistillimage@loc.gov.

The **online** version of the *Guidelines* is the official document, with addendums as listed on the FADGI website at www.digitizationguidelines.gov.

The following are the major revisions to the 2023 version of these guidelines:

- Addition of the FADGI Code of Ethics for the Still Image Working Group
- Addition of Professional Staff to the FADGI Conformance Program parameters
- Updates to the descriptions of the digital image conformance evaluation parameters
- Additional language on color management as an image conformance measure
- Addition of the Gain Modulation image conformance measure (informative)
- Addition of the Modern Textual Records material category with specifications and information provided by the National Archives and Records Administration
- Values for evaluation criteria presented as L*a*b* values rather than RGB 8-bit count values
- Removal of one-star specifications for Rare and Special collections material categories
- Updated values in the materials categories tables and the designation of certain criteria as "informative" rather than essential evaluation criteria
- Updates to the Metadata section to reflect current standards
- Updates to the Adjusting Image Files (post-processing) section to reflect current best practices
- Updates to example digitization project workflows
- Addition of the Glossary section (Appendix A)
- Removal of the Resources and Technical Implementations sections – this content can now be found on the FADGI website linked to this page: https://digitizationguidelines.gov/guidelines/digitize-technical.html

1.3 FADGI Glossary

See Appendix A of this document for a glossary of terms found in these guidelines. Please refer to the full FADGI Glossary for more extensive definitions of digitization terminology at http://www.digitizationguidelines.gov/glossary.php. Note that the online glossary definitions are the most up-to-date.

Also see ISO 19262 for additional detail at https://www.iso.org/standard/64219.html.

Chapter 2: The FADGI Conformance Program

2.1 The FADGI Star System

The International Organization for Standardization ISO 19264 document defines image quality in a three step system that includes Levels A, B and C. Nominally, FADGI corresponds to these three levels as Four Star (Level A or best), Three Star (Level B or good) and Two Star (Level C or acceptable). Additionally, FADGI provides guidance for a One Star conformance for some imaging tasks. One-star imaging does not conform to the ISO 19264 standard, and is offered by FADGI for reference use only. See the descriptions of the four FADGI Star levels below.

The FADGI process places high importance on image quality consistency. Individual guidance for each subset of content type may place greater importance on one or more of the measured parameters, and may not measure some of the parameters at all. This is an important refinement to the ISO 19264 metrics which takes into account the type of materials being imaged, and the intended use of the digital images being created.

Earlier versions of the *FADGI Guidelines* used RGB 8-bit count values and other measurement methods that are no longer appropriate. As a result, you will find that throughout these guidelines, measurements are changed to L*a*b*. The earlier count value guidance is still present in some places for reference, but will not precisely match the L*a*b* values. Earlier values do not validate FADGI conformance for newly-produced images (following the publication of this document) and are no longer valid for 2023 version conformance.

A digital object's star rating is determined by meeting the FADGI evaluation parameters through image analysis. A narrative description of the star system ratings is summarized below:

One-Star imaging is appropriate for applications where the intent is to provide a reference to locate the original or when there is no ability to image to a higher star level. FADGI recognizes that there are many reasons why imaging to higher star levels is not possible, but conformance to FADGI guidance for other aspects of an imaging program can be highly beneficial. A one-star rating is an excellent starting point for any program that wishes to begin standardized imaging but may not have the necessary support or experience to achieve a higher rating.

Two-Star imaging is appropriate where there is no reasonable expectation of having the capability to achieve three-star conformance, or when three-star conformance is not needed for the intended use of the digital image. Two-star conformance is the minimally acceptable rating for most professional digitization activity.

Three-Star imaging is defined as producing a very good professional image that is appropriate for most uses.

Four-Star defines the best imaging practical today. Images created at the FADGI four-star level represent the current state of the art in image capture. Generally speaking, the four-star level is an appropriate goal for smaller scope projects as it tends to be more achievable.

Our mission is to define what is practical and achievable today, and provide you with the knowledge and tools appropriate for your program. Generally, in order to avoid future rescanning and given the high cost and effort involved in digitization, FADGI does not recommend digitization to less than a three-star level when possible, and cautions against imaging to four-star level for all but the most sophisticated imaging programs. The FADGI program balances the desire for quality with the limitations of individual digitization programs.

2.2 Components of FADGI Conformance

There are four primary components of a FADGI compliant digitization program:

Technical Guidelines and Imaging Parameters

This consists of the guidance included in this document as well as other guidance that may be appropriate from a variety of sources, such as the International Organization for Standardization (ISO), equipment manufacturers, professional associations, and imaging consultants. No one source of information is comprehensive or exclusive.

Best Practices

These are documented workflows and processes that include guidance on addressing common challenges or situations, which may be unique to your program or follow established workflows developed by others. These should be based on a continuous improvement process methodology.

Digital Imaging Conformance Evaluation

All FADGI-conforming digitization programs must incorporate repeatable and reliable methods of validating the consistency and accuracy of imaging “goodness” as defined in this document for the various types of materials covered in this document. Once conformance is established, it’s important to not make changes to digitization workflows or production environments. Testing should be conducted any time that any conditions changed.

For imaging tasks outside of the scope of this document, appropriate methods of measuring and monitoring production must be developed and incorporated into the production workflow. FADGI would appreciate your input for additional imaging processes to be incorporated in future editions of these guidelines, or as addendums to this document as appropriate.

Professional Staff

FADGI compliant digitization is a complex, highly technical process that requires skillsets spanning a number of separate but related fields. Beyond the need for understanding photographic and digital imaging processes, staff need training in proper care and handling of materials and need an understanding of the total lifecycle of the digitization program. No claim of FADGI conformance can be made for programs that do not have appropriately trained staff and do not provide ongoing staff professional development.

These elements, when implemented together, form a FADGI-compliant digitization environment.

2.3 Digital Image Conformance Evaluation Process Monitoring

A digital image conformance evaluation program provides the measurement and monitoring component of a FADGI-compliant digitization program. Such a program consists of two components:

- Image Targets, both reflective and transmissive
- Analysis Software

Imaging targets have been designed to comply with various ISO specifications, and the parameters as defined in the FADGI program have been validated through years of use at participating Federal agencies.

It is beyond the scope of our mission to validate or recommend targets and software, however, they may be incorporated into professional digitization programs which meet the ISO 19264 standard and can therefore claim conformance to the ISO standard. Please refer to the FADGI website Resources page for examples of targets and software that are appropriate for FADGI-conforming imaging programs.

2.4 Evaluation Parameters

The FADGI guidelines establish quality and performance goals for the four levels of the star ranking system. Digital image conformance testing tools, when used with appropriate testing targets, provide the user with precise and repeatable analysis of the imaging variables that comprise FADGI star ratings. As noted above, measurements are now changed to L*a*b*. Count values from earlier versions of these guidelines have been removed. Please see the Resources page for these guidelines for more information on these changes (https://www.digitizationguidelines.gov/guidelines/digitize-technical-resources.html).

Certain evaluation parameters are strictly informative and do not validate FADGI conformance for newly-produced images. They appear as white rows with light gray text in the tables with measurement parameters in Chapter 3.

The parameters used to determine FADGI conformance are described below.

2.4.1 Sampling Frequency

This parameter measures the potential spatial resolution of a digital image, and is computed as the physical pixel count in pixels per inch (ppi) or pixels per millimeter. Ultimately, this parameter informs us about the size of the original and also provides part of the data needed to determine the potential level of detail recorded in the file. ISO 12233:2014 defines the resolution measurements.

The Resolution (Sampling Frequency) criteria in the tables for each material category (Chapter 3, beginning on page 27) include a tolerance for the Reproduction Scale Accuracy percentage. Please see the description of that criteria below for more information on the relationship between the two parameters.

The tables in the following chapter include the minimum sampling frequency in ppi for each content category to meet each star level of FADGI compliance. It’s important to analyze the source material and select a resolution that’s appropriate based on the physical attributes of the item, as well as the relationship between the item’s size and the level of detail desired.

2.4.2 Tone Response (OECF)

Opto-Electronic Conversion Function (OECF) is a description of how the digital imaging system converts light into digital values. ISO 14524:2009 defines the OECF measurement. Most imaging systems for consumer and professional applications “optimize” the tone response to create a visually appealing representation of the scene. This is commonly known as an “S” curve, where the midtone of the image is straight and both highlight and shadow portions of the scene are rendered for a more pleasing image. These optimizations are not standardized between manufacturers and pose challenges to restore to the linear tone response essential for cultural heritage digitization. The measurement for this metric is made in colorimetric L* units (noted as ΔL_{2000}* where Δ represents the delta).

Note: The Tone Response (OECF) values for transmissive material types in the following chapter have been determined to best capture the tones in the original transmissive item (film, negatives, etc.). Any other adjustments to the image will be done during post-processing. These guidelines focus on accurate capture of the transmissive original, while other adjustments to create a more “pleasing” derivative may be done after capture. The values for transmissive collection types are considered provisional. This is indicated in the evaluation parameters tables in Sections 3.9, 3.10, 3.11, 3.12, and 3.14.

2.4.3 Gain Modulation

The gain modulation is a measure of the localized slope of the OECF (tone response) when plotted as L_{out}* (y-axis) versus L_{in}*(x-axis). Its primary benefit is to objectively measure and detect clipping or soft clipping distortion behaviors by way of the OECF or tone scale curve. Ideally the slope of the OECF curve should be sufficiently high to make L_{in}* values easily recoverable from the L_{out}* values without introducing quantization or posterization artifacts. If the slope of the above L* curve is too low, deriving original L_{in}* values from captured L_{out}* values becomes ambiguous, especially in the presence of image noise. Most clipping behaviors occur at the extreme values of the L_{out}* vs. L_{in}* curve.

It should be noted that the upper and lower L* tolerances for 3- and 4-star levels often catch such clipping behaviors by themselves. This is typically not the case for 1- and 2-star levels though. This is where the gain modulation metric offers an additional advantage.

Note: In this revision, this metric is informative only, and not required for evaluating whether an image is FADGI-compliant. As such the rows for this metric are shaded white to differentiate them from the gray rows with the required metrics in the tables in the next chapter.

2.4.4 White Balance Error

This is a measurement of the color neutrality of the digital file. The definition of neutral is not universal. RGB workflows that use digital count values encode neutral as defined by the International Color Consortium (ICC) color space chosen. L*a*b* workflows define neutral as 0 on the a* axis and b* axis, with the lightness recorded from 0-100 on the L* axis. Digitization workflows are increasingly adopting the L*a*b* color mode. It is worthwhile noting that the gray patches used for measuring white balance will never truly have a* and b* values of zero. Typically, these values are sufficiently small to ignore in day-to-day workflows. Nevertheless, these small values can be accommodated for in reporting colorimetric white balance by removing the slight bias.

There are several other color models that are used by various applications. Key to successful FADGI conformance is the establishment of the correct white balance before beginning the ICC calibration process. The metric for colorimetric evaluation of white balance is similar to the color accuracy ΔE_{2000} metric, with the exception that the L* component is eliminated. The resulting metric is defined as ΔE(a*b*).

Note: The values for transmissive collection types are considered provisional. This is indicated in the evaluation parameters tables in Sections 3.9, 3.10, 3.11, 3.12, and 3.14.

2.4.5 Lightness Uniformity

It is not possible to create a perfectly even field of illumination without the use of software that takes into account the inherent fall-off of all lenses and the limitations of lighting systems. Ideally, there should be a perfectly even recording of a neutral reference from center to edge and between points within the image.

ISO 17957:2015 defines the shading measurements. Specific values are defined in each section of the guidelines. Flat fielding software using captured data from extended and uniform matte surface targets provides a simple and effective method of reducing non-uniformity, but should not be a substitute for good professional imaging technique. Aggressive corrections can in themselves introduce digital noise artifacts into the finished image file. Target surfaces with glossy or semi-gloss surfaces should be avoided.

Note: The values for transmissive collection types are considered provisional. This is indicated in the evaluation parameters tables in Sections 3.9, 3.10, 3.11, 3.12, and 3.14.

2.4.6 Color (Encoding) Accuracy

True color accuracy can only be evaluated once a digital image has been rendered as a physically measurable color to print or display. It is important to understand that a digital image, in the context of FADGI, is an encoding of color as delivered by any number of digital image file formats. We treat color accuracy here as if the color code values are idealized virtual colors as interpreted by assigned color profiles or color working spaces. These color profiles and color spaces can be considered color dictionaries for translating image code values into idealized rendered colors. For simplicity in communication, we continue to describe this metric as ‘color accuracy’ with the understanding that doing so requires the use a working color space dictionary for interpretation of RGB values to standardized working color space.

There is no perfect imaging system or perfect method of color evaluation. Color accuracy is measured by computing the color difference (ΔE_{2000}) between the decoded imaging results of an assigned color working space to the pre-measured color values of a color target. By imaging an appropriate target and evaluating it through software, variances from known values can be determined, which is a good indicator of how accurately the system is recording color. Software programs generally measure the individual patch values and also provide the average deviation of all color patches measured (the mean). Refer to ISO 13658:2000 for additional documentation on color accuracy measurement.

As a general rule, targets with a small number of color and density patches can provide a good analysis of system consistency, but cannot provide information suitable for creating ICC color profiles. Targets with 100 or more measurement patches will provide a better input to ICC profile creation software when making ICC camera (input) or master file (output) profiles.

Profiling for printer calibration is done using targets generated by the ICC profiling software in use and printed on the specific device being calibrated. This involves the measurement of hundreds or thousands of printed reference patches, which are then compared to the values in the digital file being printed. Printers generally have a far less linear response requiring more data points to properly calibrate. Digital image conformance evaluation targets are not appropriate for the calibration of printers.

A note of caution: there are many manufacturers of devices which measure reflective and transmissive color. However, each manufacturer has their own standard for calibration of their instruments, and measurements can vary between properly calibrated devices from different manufacturers. For the most consistent results imaging devices should be re-certified on a rotating schedule, with the before and after recertification values recorded for comparison. Take care to use the same target for both before and after recertification, ideally a target designed to be a stable reference. Target and device variability are a primary cause of inconsistent imaging stability.

2.4.7 Color Channel Misregistration

All lenses focus red, green, and blue light slightly imperfectly. This parameter measures the spatial dislocation of red, green, and blue light in terms of pixels of misregistration. This parameter is used in the evaluation of lens performance. Poor registration of the three color channels can indicate equipment issues, poor conditions, etc. Alternate terms used for this metric are color fringing, chromatic aberration, and lateral color error, which all fall into the general category of lens aberrations.

2.4.8 SFR* (Spatial Frequency Response)

*Note: The SFR is a surrogate metric to Modulation Transfer Function (MTF). There are some very minor differences between SFR and MTF. In the purest sense SFR may not give the same results due to assumptions about linearity and the response at the zero frequency. For simplicity we continue to use SFR as our metric in this document. For field use SFR is much easier to calculate.

It is related to the sharpness, focus, and ability to resolve fine details. The SFR is a functional (i.e. multi-valued) relationship, which defines an imaging system's ability to maintain contrast of increasing smaller details. Figure 1 (below) illustrates this. There are several single valued metrics to describe the SFR function. These include measurements at specific points on the curve, such as the 50% and 10% response points as well as the response at the highest frequency supported by the sampling frequency. ISO 12233:2000, ISO 16067-1:2003, and ISO 16067-2:2004 define SFR measurement.

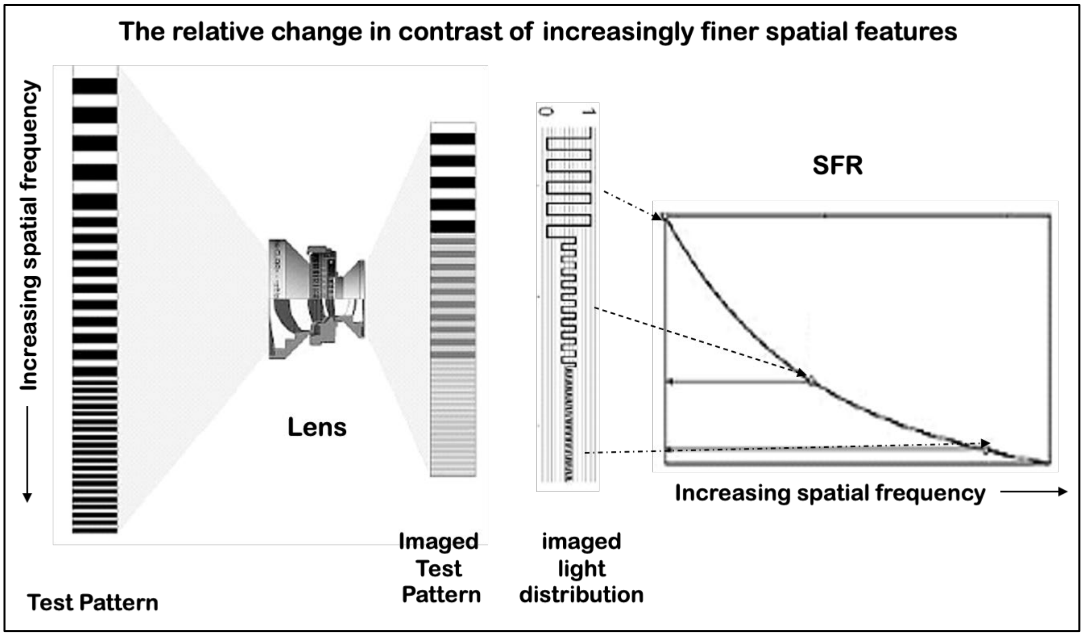

Figure 1 : Graphical Illustration of SFR using a resolution test pattern imaged by a lens showing loss of contrast with increasing spatial frequency

Since the Spatial Frequency Response (SFR) is a functional relationship with many data points, it is difficult to specify an absolute curve shape unequivocally. Therefore, single numbered metrics have been developed to summarize the important characteristics of the SFR. These include, SFR50, SFR10 (Sampling Efficiency), SFR Response at Nyquist Frequency, Max SFR, and SFR Abnormal Behavior (under development). A description of each of these metrics follows:

- SFR50: This is a measurement which determines the frequency when the spatial frequency response (SFR) has a value of 50% modulation. That is, only 50% of the original content contrast has been maintained for that level of detail. In order for this frequency to be compared across images of any arbitrary sampling frequency, e.g. 300, 400, 600 ppi, the value is normalized to the half sampling (Nyquist) frequency and expressed as a percentage. For example, if an image captured at 400 ppi has an SFR with 50% modulation at the 120 ppi level of detail, then the SFR50 metric is expressed as 60% [(120 / 200) *100]. Note: The half sampling (Nyquist) frequency is half of 400 ppi or 200 cycles/inch. This is because it takes two pixels to define a cycle. The formula relating ppi to cycles per inch is shown below.
- SFR10 (Sampling Efficiency): This is a measurement which determines the frequency when the spatial frequency response (SFR) has a value of 10% modulation. Again, the measured frequency is normalized to the half sampling (Nyquist) frequency and expressed as a percentage. For example, if the SFR curve has 10% modulation at 180 ppi for an image captured at 400 ppi, the sampling efficiency would be expressed as 90% [(180 / 200) *100].
- SFR Response at Nyquist Frequency: This is a measurement of the spatial frequency response at exactly the half sampling (Nyquist) frequency. Note: In this revision, this metric is informative only, and not critical for evaluating whether an image is FADGI-compliant. As such the rows for this metric are shaded differently than the critical metrics in the tables in the following sections.

- SFR Abnormal Behavior: This is a metric to be developed, which will try to identify and characterize non-typical SFR shapes, most likely caused by some post-processing. Since it's still under development, it's not included in the evaluation parameter tables in the following chapter.

- Sharpening (Max SFR): This is a measurement of the maximum value of the SFR function. If the modulation exceeds 1.0 (100%), it can be an indication of digital enhancement filtering. Figure 2 at right shows in more detail how contrast is reduced at higher spatial frequencies.

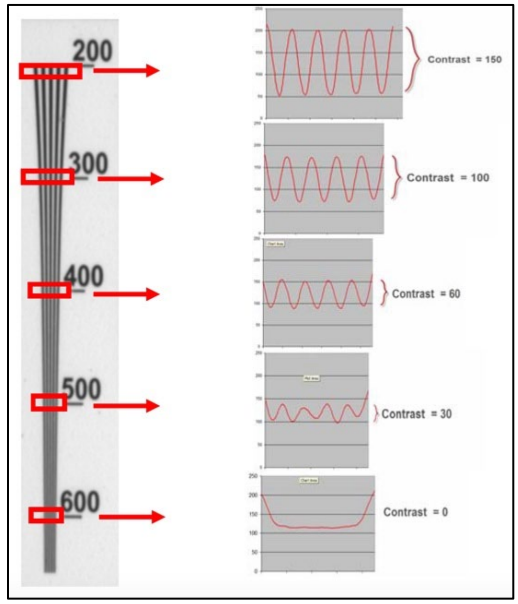

Figure 2: Light intensity cross sections of resolution wedge at different ppi line spacing

2.4.9 Reproduction Scale Accuracy

This parameter measures the relationship between the size of the original object and the size of that object as calculated from the digital image metadata. This parameter is measured in relation to the pixels per inch (ppi) or pixels per millimeter (ppmm) of the original digital capture. For example, capturing an image of a ruler at 400 ppi will digitally render the ruler at the correct size when displayed or printed at 400 ppi. It is critically important in cultural heritage imaging to maintain the relationship to the original size of the object. Too often, accurately populating the metadata with the correct ppi at capture is treated casually.

Calculating the reproduction scale accuracy requires the resolution value defined in the header of the image file. This value becomes the target/reference resolution that the image content is measured against. If this information is missing from the header of the image file, the image is not FADGI compliant.

The original size of microfilmed documents can only be determined if the filming "reduction ratio" is known, or there is a physical ruler in the image area, which is not normal practice. The reduction ratio is referred to as 8x or 10x (or other) reduction, indicating that the magnification of the image on the microfilm is 1/8th or 1/10th the size of the original document. This may or may not be known when digitizing microfilm. Unless noted in metadata, the scale of the original will be lost when microfilm is digitized. Microfilm is digitized at a fixed ppi resolution, regardless of the original "reduction ratio."

Photographic film cannot be related to a reproduction scale, unless there is a physical measurement in the image to scale to. Photographic film is digitized to appropriate resolutions relative to the size of the film and the capabilities of the digitization system.

2.4.10 Sharpening

Almost all digital imaging systems apply sharpening, often at a point where the user has no control over the process. Sharpening artificially enhances details contrast to create the illusion of greater definition. Digital image conformance evaluation testing quantifies the level of sharpening present. There are three major sharpening processes in a typical imaging pipeline: capture sharpening (through camera setting adjustment), image sharpening in post processing, and output sharpening for print or display purposes. Sharpening is usually implemented through image edge enhancement, such as filtering techniques using unsharp masks and inverse image diffusion. There is nothing inherently wrong with sharpening files at any of these three steps, unless doing so decreases the image quality "goodness". Modern digital cameras and scanners often apply a significant amount of image processing to captures by default, much of which cannot be turned off. However, sharpening is irreversible, and best practice for archival master files is to limit the amount of sharpening applied to master files.

The examples in Figure 3 below show the visual and SFR differences between a sharpened but low resolution image on the left, compared to an unsharpened but high resolution image on the right. Once the SFR of the left image is below the 10% level (i.e. 90% contrast loss) there is no way to reliably recover the higher resolution information seen in the right image. Notice the inset and enlarged portions of the clock feature. The minute marks are much clearer in the unsharpened image.

Figure 3: Example difference between sharpening (left) and resolution (right)

As noted above, the lower frequencies of the SFR of the left image in Figure 3 have been selectively enhanced in contrast via image processing. Figure 4 (right) shows a graphical representation of the relationship between resolution and sharpness.

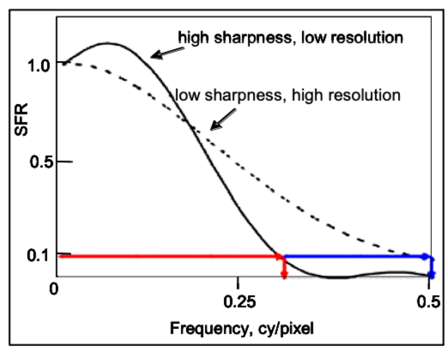

Figure 4

2.4.11 Noise

Generally, noise can be defined as any small scale or pixel-to-pixel variability in L* or RGB count values. A good example is the kind of granular deviation or grain (i.e. noise) seen in photographic film. In other words, any unexpected count value or L* deviations at the pixel-to-pixel level. This requires a test target feature with very low texture or grain itself. Very simply, noise is calculated as the standard deviation of L* values within the region of interest of a given gray patch.

Noise in digital images can take on a whole new meaning because of image processing artifacts. For instance, standard JPEG processing introduces 8x8 pixel blocks that are clearly not part of the original content. In many cases camera/scanner user interfaces often allow for some form of noise cancelling or de-noising. As with sharpening selections, users should use these in moderation. Aggressive de-noising selection can completely remove any naturally occurring texture in a scanned object leading to unnatural appearing images. For instance, the texture or tooth in parchment or textured papers may be completely removed. This is why we have inserted cautionary alerts in the FADGI noise metric sections for any noise values less than an indicated value. Noise values that are too low are a possible sign of aggressive de-noising selections

Noise levels will also increase with aggressive sharpening selections, high ISO speed settings, and short exposure times. Noise cannot be measured using a target with any kind of surface texture. The target should have a smooth or glossy surface.

2.4.12 Skew & Rotation

Skew and rotation are similar geometric distortions but have distinctly different characteristics. Examples of each are shown below in Figure 5. The middle image shows the starting content. The page content is rectilinear and the sides are perfectly horizontal and vertical with 90° angles between **all** adjoining sides. The left image is a skewed version. None of the intersecting angles are at 90°. Even if one of the angles was not at 90°, it would still be considered skewed. Skew behaviors in the captured image can often be traced to lack of parallelism between the focal plane of the camera and the platen.

Rotation keeps all the parallel features of the opposite sides and maintains 90° angles at all corners and is introduced at capture by improper content alignment at capture.

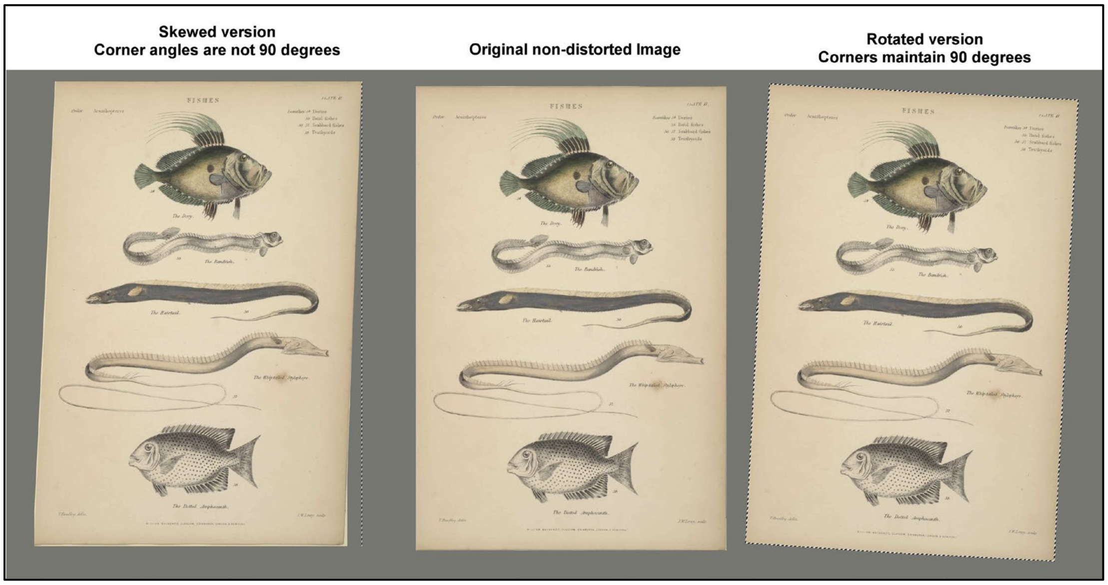

Figure 5

These parameters measure how straight the image is in the file. Skew and rotation are the angle of deviation in a digital image from the paper edge, text lines or other visual reference elements of the original item. Master image files should be straight in relation to the contents of the image. The guidelines now allow for rotation correction to be applied to images.

2.4.13 Geometric Distortion (Partially Implemented)

Critically important to faithful reproduction of an original is the management of geometric distortion in image capture. Typical camera lenses are poorly corrected for this, and create images which exhibit significant distortion even under ideal conditions. If the imaging system is not correctly aligned, other distortions are introduced to the image as well. Cultural heritage imaging requires high quality optics designed for minimal geometric distortion. Recently digital correction processes have been introduced to “correct” for the distortions created by lenses from many manufacturers. While these software approaches are interesting and often effective, they interpolate pixels which causes loss of image integrity. High quality lenses designed for copy work will generally have very well-controlled geometric distortion, and should not be corrected further through software for master files. ISO 17850:2015 defines the geometric distortion measurements for digital cameras.

2.4.14 Field Artifacts (Future Implementation)

Ideally, digitization should only capture what is in the original object. However, dust, dirt, and scratches almost inevitably find their way into digital files. This parameter quantifies the physical non-image artifacts in a digitization system. It should be noted that this parameter refers to artifacts ON the object, not other artifacts like sensor dust. Current best practice involves post-capture physical inspection for non-image artifacts, and noting their frequency to inform the appropriate level of post-process inspection. Editing out artifacts should only be done to derivative files.

2.4.15 Highlight/Shadow, Tolerance

Unlike for reflective materials, where the colorimetry can be scene-referred, for transparencies the true colorimetry of the original scene is lost. Instead we only have a proxy to the original scene, i.e. the original scene imaged onto the film. This is an emerging area and the final values are provisional/informational.

2.4.16 Dynamic Range

Dynamic range is the difference of the minimum and maximum density values an imaging system can capture (D max minus D min). The dynamic range is calculated for both capture systems and source material. This is an emerging area and the final values are informative only.

2.4.17 Color Management

As of the date of this publication, ICC color management is the most widely used process of attempting to correct for the many variables inherent in the digital imaging process. Each component of the image capture cycle influences the rendering of the digital image, and no two image capture systems are identical. There are many, many approaches to resolve these differences, and just as in the capture process itself, most do not achieve the same result given the same input.

As a result, we still cannot achieve consistently similar imaging using a mixed bag of imaging systems and color calibration methods and software.

There is no fix to this issue if device-level color management solutions are used. Unless all of the imaging conditions, including cameras/scanners/software/lighting/lenses etc. are identical, there is little chance you will be able to calibrate these components to function as a controlled system.

However, if a system-level approach to color management is employed, you can achieve remarkably consistent results between all of the imaging systems in your environment. To implement a system-level color management approach, an ICC profile creation capable target is imaged at the start of each imaging session on each device. This serves as ground truth. There are many available in current use throughout the imaging community. While one may have an advantage over another, all can be made to work.

The next step in the process involves the creation of an ICC profile for each of the imaging sessions, and applying that profile to the session images. The resulting color corrected files are then converted to the desired master ICC color space. FADGI highly recommends a system-level color management approach for all but the smallest of digitization programs.

Using a system-level batch conversion process can also serve to validate and correct other aspects of the imaging process, and some of these programs can even provide a 3D view of the resulting image file

An overview of the ICC color management process follows:

International Color Consortium (ICC) Color Management System

ICC-based color management consists of four components that are integrated into software (both the operating system and applications).

- PCS (Profile Connection Space)
    - Typically, end users have little direct interaction with the PCS. It is one of two device-independent measuring systems for describing color based on human vision, and is usually determined automatically by the source profile.
- Profile
    - A profile defines how the numeric values that describe the pixels in images are to be interpreted, by describing the behavior of a device or the shape and size of a color space. There are currently two basic ICC profile types in use: v2 and v4. They do not achieve the same results.

- Rendering Intent
  - Rendering intents determine how out-of-gamut colors will be treated in color space transformations. There are four of these: Perceptual, Relative Colorimetric, Absolute Colorimetric, saturation.
- CMM (Color Management Module)
  - The CMM performs the calculations that transform color descriptions between color spaces. There are many of these in use, most achieve slightly different results.

Color Profiles

Profiles are sets of numbers, either a matrix or lookup table (LUT), that describe a color space (the continuous spectrum of colors within the gamut, or outer limits, of the colors available to a device) by relating color descriptions specific to that color space to a PCS. This is a complicated subject that few understand, and even fewer know when to use either the Matrix or LUT approach. There are entire books on this subject and the internet has dozens of articles on the subject. For most uses, stay with the recommendations of the systems providers you have chosen.

Although files can be saved with any ICC-compliant profile that describes an input device, output device or color space (or with no profile at all), it is best practice to adjust the color and tone of an image to achieve an accurate rendition of the original in a common, well-described, standard color space. This minimizes future effort needed to transform collections of images, as well as streamlines the workflow for repurposing images by promoting consistency. Although there may be working spaces that match more efficiently with the gamut of a particular original, maintaining a single universal working space that covers most input and output devices has additional benefits. Should the profile tag be lost from an image or set of images, the proper profile can be correctly assumed within the digitizing organization, and outside the digitizing organization it can be reasonably found through trial and error testing of the small set of standard workspaces.

Some have argued that saving unedited image files in the input device space (profile of the capture device) provides the least compromised data, and allows a wide range of processing options in the future; but these files may not be immediately usable and may require individual or small batch transformations. The data available from the scanner has often undergone some amount of adjusting beyond the operator's control, and may not be the best representation of the original. We recommend the creation of master image files using a standard color space that will be accurate in terms of color and tone reproduction when compared to the original.

The RGB color space for master files should be gray-balanced, perceptually uniform, and sufficiently large to encompass most input and output devices. Color spaces that describe neutral gray with equal amounts of red, green, and blue are considered to be gray-balanced. A gamma of 2.2 is considered perceptually uniform because it approximates the human visual response to stimuli.

The Adobe RGB (1998), ProPhoto and ECIRGB_v2 color space profiles adequately meet these criteria and are recommended for storing RGB image files. These color spaces have reasonably large color gamuts, sufficient for most purposes when saving as 48-bit RGB files. Gray Gamma 2.2 (16-bit) is recommended for grayscale images.

Rendering Intents

When converting images from one color space to another, one of four rendering intents must be designated to indicate how the mismatch of size and shape of source and destination color spaces is to be resolved during color transformations: perceptual, saturation, relative colorimetric, or absolute colorimetric. In general, we have found that perceptual intent works best for photographic images, while absolute colorimetric works best for images of text documents and graphics. It may be necessary to try all of the potential rendering intents to determine which will work best for a specific image or group of images. The use of a 3D gamut visualization software greatly assists this effort.

When perceptual intent is selected during a color transformation, the visual relationships between colors are maintained in a manner that looks natural, but the appearance of specific colors is not necessarily maintained. As an example, when printing, the software will adjust all colors described by the source color space to fit within a smaller destination space (printing spaces are smaller than most source or working spaces). For images with significant colors that are out of the gamut of the destination space (usually highly saturated colors), perceptual rendering intent often works best.

Relative colorimetric intent attempts to maintain the appearance of all colors that fall within the destination space, and to adjust out-of-gamut colors to close, in-gamut replacements. In contrast to absolute colorimetric, relative colorimetric intent includes a comparison of the white points of the source and destination spaces and shifts all colors accordingly to match the brightness ranges while maintaining the color appearance of all in-gamut colors. This can minimize the loss of detail that may occur with absolute colorimetric in saturated colors if two different colors are mapped to the same location in the destination space. For images that do not contain significant out of gamut colors (such as near-neutral images of historic paper documents), relative or absolute colorimetric intents usually works best.

Color Management Module

The CMM uses the source and destination profiles and the rendering intent to transform individual color descriptions between color spaces. There are several CMMs from which to select, and each can interact differently with profiles generated from different manufacturers' software packages. Because profiles cannot provide an individual translation between every possible color, the CMM interpolates values using algorithms determined by the CMM manufacturer and each will give varying results.

Profiles can contain a preference for the CMM to be used by default. Some operating systems allow users to designate a CMM to be used for all color transformations that will override the profile tag. Both methods can be superseded by choosing a CMM in the image processing application at the time of conversion. We recommend that a CMM that produces acceptable results for project-specific imaging requirements be chosen, and switched only when unexpected transformations occur.

2.5 File Formats

2.5.1 Master File Format

The choice of master file format is a decision which affects how digitized materials can be used and managed. There is no one correct master file format for all applications; all format choices involve compromises between quality, access and lifecycle management. The FADGI star system tables list the most appropriate master file formats for each imaging project type. Selection of the most appropriate format within these recommended choices is an important decision that should be consistent with a long-term archive strategy.

One or more digital master files can be created depending on the nature of the originals and the intended purpose of digitization. Digitization should be done in a "use-neutral" manner, and should not be geared for any specific output. If digitization is done to meet the recommended image parameters and all other requirements as described in these guidelines, we believe the master image files produced should be usable for a wide variety of applications and outputs.

FADGI defines two master file types, described below.

Archival Master:

Archival master files represent the best copy produced by a digitizing organization, with *best* defined as meeting the objectives of a particular project or program and being suitable for the generation of production master files and derivative files. In some cases, an institution may produce more than one archival master file. Archival masters should have a long straight line tonal scale, wide color gamut, and be minimally adjusted to be use-neutral. Archival masters should have a linear gamma, which displays as visually flat. A gamma-corrected master file would be considered a production master. The terms used to name types of files vary within the digital library and digital archiving communities. In many cases, the best copies are called *preservation master files* rather than *archival master files*

Archival master files represent digital content that the organization intends to maintain for the long term without loss of essential features. Digital formats for archival master files must meet the requirements of the sustainability factors. If the existing format is deemed sustainable for the long term, the files are retained as-is and called *archival masters*. If the existing format is deemed unsuitable for long-term retention, e.g., it is an obsolescent format, then the content may be transcoded and the new version retained as the archival master. If there is risk of data loss from the transcoding, files in the existing format may also be retained for possible future reference.

Best practice dictates that master files should be lossless. If there are storage space constraints, other members of the organization in addition to archivists or digitization staff may be consulted on the organizational policy for master file formats. This may include IT or general counsel, but may differ from organization to organization. The limitations of storage and/or display systems should not be a final determinant of file format policies. Archival files may be different than access files (see Section 2.5.2 below).

Production Master:

Production master files are produced by processing the content in one or more archival master files, resulting in a new file or files with levels of quality that rival those of the archival master.

One type of processing consists of the assembly of a set of segments into a unified reproduction of an item. For example, an image of a large map may be produced by stitching together a set of image tiles, each representing a portion of the original paper item.

Other processes that may be applied include aesthetic or other technical corrections to the original file. When both the uncorrected and corrected representations are retained, the uncorrected files are *archival master files* and the corrected versions are *production master files*. For most preservation-oriented archives, aesthetic changes will be modest. For images, aesthetic changes may include such things as adjusting tonality. Certain technical changes may be more significant. For example, the *archival master* version of a pictorial image may employ a linear representation of light intensity (see the explanation in gamma), while the production master may employ gamma correction. The transformation from linear to gamma-corrected is not reversible in a mathematically exact manner.

Master files of all types have permanent value for the digitizing organization and should be managed in an appropriate environment, e.g., one in which read and write executions are minimized and other preservation-oriented data management actions are applied. In contrast, derivative files are frequently accessed by end-users and are typically stored in systems that see repeated read and write executions.

Detail on master formats can be found at

http://www.digitizationguidelines.gov/guidelines/raster_stillImage_compare.html

2.5.2 Access File Formats

FADGI anticipates continual evolution in the availability of access file formats, each new format designed to provide specific advantages over others for a specific application. These guidelines provide recommendations for a few of the most appropriate for cultural heritage imaging. Note that many access formats are no longer in use and content created with them may be no longer accessible. Care should be taken when selecting access formats to insure long-term viability.

Often called *service*, *access*, *delivery*, *viewing*, or *output* files, derivative files are by their nature secondary items, generally not considered to be permanent parts of an archival collection. To produce derivative files, organizations use the archival master file or the production master file as a data source and produce one or more derivatives, each optimized for a particular use. Typical uses (each of which may require a different optimization) include the provision of end-user access, high quality reproduction, or the creation of textual representations via optical character recognition (OCR), handprint character recognition (HCR), or handwritten text recognition (HTR). In many cases, the derivatives intended to serve end-user access employ lossy compression, e.g., JPEG-formatted images. The formats selected for derivative files may become obsolete in a relatively short time.

2.5.3 File Compression

Compression may be appropriate for both master and derivative files. Significant benefits can result from the appropriate use of file compression. The type of compression and file format can be dependent on cost of storage space, amount of available space, type of application, etc. Lossless compression such as LZW and JPEG 2000 (wavelet) are approved for all uses. Lossy compression may be appropriate for specific applications or end uses. In considering the use of compression, the combination of the file format and the compression should be evaluated for long-term sustainability as a system. Compression techniques using patented or proprietary programs should be avoided due to long-term sustainability concerns.

2.5.4 File Format Comparison

The choice of file format has a direct effect on the performance of the digital image as well as implications for long-term management of the image.

The go-to master file format for still digital imaging has been TIFF v6 for decades. This format has, and continues to serve our community well. However, this format creates master files that are excessively large which dramatically increases the storage requirements and long term cost. FADGI recommends considering JPEG2000, 20:1 compression for most applications. This provides a 95% reduction in file size with no visible loss. Be very careful in the selection of file formats for your applications, and avoid the temptation to change formats frequently.

Additional information on file formats and format selection can be found on the Library of Congress Sustainability of Digital Formats site at https://www.loc.gov/preservation/digital/formats/index.shtml, and at the Library's Recommended Formats page at https://www.loc.gov/preservation/resources/rfs/.

2.6 Physical Environment

Standardization of the digitization environment creates a workspace where the variables of visual perception can be controlled. Without standardization, perception of image quality may vary dramatically. In an imaging environment where human judgement is a factor, standardization of the physical environment is critically important to maintaining consistency. The recommendations that follow address the most common issues related to a proper physical environment for digitization.

2.6.1 Room

The working environment should be painted/decorated a neutral, matte gray with a 60% reflectance or less to minimize flare and perceptual biases.

Monitors should be positioned to avoid reflections and direct illumination on the screen.

ISO 12646 requires the room illumination be less than 32 lux when measured anywhere between the monitor and the observer, and the light a color temperature of approximately 5000K with a color rendering index (CRI).[1] above 90. Consistent room illumination is a fundamental element of best practice in imaging. Changes in color temperature or light level from a window, for example, can dramatically affect the perception of an image displayed on a monitor. There are hand-held color meters on the market that provide these measurements. Investing in one of these is highly recommended, and the user will likely find many other applications where such a device is highly valuable.

Each digitization station should be in a separate room, or separated from each other by sufficient space and with screening to minimize the light from one station affecting another.

Care should be taken to maintain the work environment at the same temperature and humidity in which the objects being imaged are normally kept. Variations can cause stress to some materials and in extreme cases may damage the originals. Environmental data loggers monitor and record changes in conditions over time, and using such loggers in both imaging and storage areas is highly recommended. Additional information about environmental data loggers can be found in this National Park Service publication at https://www.nps.gov/museum/publications/conserveogram/03-03.pdf

While specific temperature and humidity recommendations are beyond the scope of this document, adherence to American Institute for Conservation of Historic and Artistic Works (AIC) guidelines is recommended. Please visit their site at https://www.culturalheritage.org/ and their preventive care resources at https://www.conservation-wiki.com/wiki/Preventive_Care.

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[1] https://www.lumens.com/the-edit/the-guides/understanding-color-rendering-index/

2.6.2 Monitor, Light Boxes, and Viewing Booths

The trio of monitor, reflection viewing booth, and transmission light box can provide a calibrated reference viewing environment to accurately portray physical objects and their digital representation. If designed correctly, these create an environment suitable for cultural heritage digitization.

The lighting parameters described above are too dim to properly evaluate an original against the digital representation on a monitor. For reflective originals, a 5000k viewing booth with a CRI of 90 or better should be placed in proximity to the monitor to provide adequate illumination for comparison. For viewing transparencies, a 5000k transmissive light box, with a CRI of better than 90 should be used. For both reflective and transmissive viewing, the luminance of the light box should be adjusted to match the luminance of the monitor. Viewing of color and black and white negatives does not require a color-accurate environment since no color comparisons can be made with these materials. Areas beyond the reflective or transmissive image should be masked off with neutral material to prevent stray light from altering perception of the originals.

Note that the color temperature normally used for graphic arts viewing is 6500k, not the 5000k standard for photography. Many professional viewing sources are switchable between the two standards. Do not use 6500k as a viewing source.

Images must be viewed in the color space in which they will be saved, and the monitor must be capable of displaying that color space. Note that most monitors cannot display wide gamut color spaces. The illuminance of the monitor must be set to a brightness that produces a good white match to the viewing environment for the originals. The graphic card in the computer must be capable of displaying 24-bit color and set to a gamma of 2.2. There is significant confusion in the choice of display color spaces, with many newer computing systems adopting the P3 (Apple) or other color spaces, which provide new options when establishing workflows and use cases. Be careful to align all elements of your process to the same standard.

The appropriate color temperature and illumination level of the monitor may vary based on a number of uncontrollable factors. Adjust the illumination and color temperature of the monitor to provide the best approximation of white in the viewing environment to the digital representation of white on the monitor. Refer to ISO 12646 and 3664 for additional documentation if needed. Be careful not to offset the monitor to compensate for a poor working environment.

The color of the monitor desktop should be set to L*50, a*0, b*0. This establishes a visually neutral mid-gray monitor background. Avoid using colourful imagery for desktop screensavers and menus, as these will alter your perception of images. A monitor viewing hood will also improve digital image viewing.

Careful attention must be paid to the selection of monitors for professional digital imaging. Most monitors in the marketplace cannot display Adobe RGB (1998), ProPhoto, P3 or ECIRGB_v2 color spaces. Digital images cannot be viewed accurately on a monitor that cannot display the range of color that these color spaces include. The sRGB color space is viewable on most current color monitors, but many will be lacking in other important considerations, such as contrast range. Care must be taken as well in monitor selection to assure that the selected monitor provides an adequate viewing angle without perceptible image change. For these reasons, appropriate monitors can be some of the more costly equipment required for digitization.

In order to meet and maintain the monitor settings summarized above, it is recommended that professional LCD monitors designed for the graphic arts, photography, or multimedia markets be used.

A color calibrator and appropriate software (either bundled with the monitor or a third party application) should be used to calibrate the monitor to Adobe RGB (1998), ProPhoto, ECIRGB_v2, or sRGB color space as appropriate. This is to ensure desired color temperature, luminance level, neutral color balance, and linearity of the red, green, and blue representations on the monitor are achieved and maintained.

An ICC profile should be created after monitor calibration for correct rendering of images, and the monitor calibration should be verified weekly, preferably at the beginning of the week's imaging.

Using a monitor calibrator, however, does not always ensure monitors are calibrated well. Practical experience has shown calibrators and calibration software may not work accurately or consistently. After calibration, it is important to assess the monitor visually to make sure that the monitor is adjusted appropriately. Assess overall brightness, and color neutrality of the gray desktop. Then assess a monitor calibration reference image for color, tone scale, and contrast. The use of a monitor calibration reference image is an essential element of creating and maintaining a proper digitization environment. FADGI also recommends the use of self-calibrating monitors, which can be programmed to recalibrate the system at frequent intervals, and eliminate operator error inherent in manual calibration processes.

2.6.3 Cleanliness of Work Area

Keep the work area clean. Best practice dictates carefully wiping down with an appropriate cleaning agent all equipment, excluding lenses, before work begins and again when work concludes. Scanners, platens, and copy boards will have to be cleaned on a routine basis to eliminate the introduction of extraneous dirt and dust to the digital images. Many old documents tend to be dirty and will leave dirt in the work area and on scanning equipment.

See, for example, the National Archives and Records Administration's (NARA) *Preservation Guidelines for Vendors Handling Records and Historical Material* at http://www.archives.gov/preservation/technical/vendor-training.html for safe and appropriate handling of originals. Photographic originals may need to be carefully dusted with a lint-free, soft-bristle brush to minimize extraneous dust.

The use of a HEPA high efficiency vacuum cleaner is strongly recommended. Standard vacuum cleaners will simply pass fine dust through and contaminate the air surrounding the workspace. Also, consider the use of anti-static devices appropriate for the type of work being imaged.

Washing hands with soap and water and thoroughly drying before handling collection materials is critical. Hand sanitizer should not be used prior to handling the materials. Consult an expert regarding gloves and handling best practices based on the collection.

2.6.4 Vibration

Sources of vibration include cooling fans on an imaging sensor, or movement of the sensor/original in a scanner. Even the slightest vibration will have a dramatic effect on image quality, in particular if the magnification is high. If vibration is determined to be an issue, remedial efforts including changing the scanning speed or adding vibration dampening materials to the scanner. For instant capture camera systems, the use of electronic flash lighting can effectively reduce the effects of vibration on image quality. The effects of vibration become much more noticeable when imaging at high magnifications, as is common in film digitization.

Vibration effects can and often do occur outside of the direct imaging environment too. Indoor vehicle movements, refrigeration appliances, and even subway construction create resonances that manifest as vibrations even at short exposure times.

2.6.5 Flare

Stray light entering a lens is a primary source of flare, a condition where the purity of image-forming light is degraded by extraneous light. This can also be caused by lens elements that have hazed over time and either require cleaning or replacement. Check the lens condition by looking through the lens using an LED light source and observe the clarity of the glass. While simple, this test is quite effective. The use of a lens hood is highly recommended. Reduction of stray light around the original will considerably reduce flare.

2.6.6 Lighting

All light sources have variations in their spectral power distribution. Light sources that have serious deficiencies in their spectral power distribution are unsuitable for use in a cultural heritage imaging environment. This parameter is generally measured by the *Color Rendering Index (CRI),* which is a measure of how close the spectral distribution is to the reference (the sun). A CRI above 90 is generally accepted as appropriate for most cultural heritage imaging.

Another consideration for lighting is how diffuse the source is. Highly diffuse light sources provide a soft, shadowless wash of light, but this comes at the expense of clear delineation of detail and can reduce color accuracy. On the other extreme, highly collimated, or "point" light creates a harsh rendition which can be just as undesirable. Selection of appropriate lighting is as much art as science, and is highly application-specific. See sections for specific collections materials types in Chapter 3 (page 27) for more information.

2.6.7 Accessories

A series of specialized aids are useful for cultural heritage digitization. System alignment tools lead the list. An imaging system must be parallel at the sensor, lens, and object planes. There are many aids on the market to accomplish this, the simplest of which is a spirit level, or the electronic level incorporated into many smart phones. A more accurate method involves bouncing light from an emitter device off of a reflector placed over the lens and using the reflection to measure deflection. This method allows very precise alignment with an easy-to-accomplish process. Proper system alignment is essential for quality imaging.

A basic tool kit consisting of gloves, spatulas, thin Mylar strips, weighted aids to hold materials down, foam “props” and sheets with the ability to resize them as needed, lens wipes, air duster, soft brushes, etc. should be available at each imaging station. The contents can be refined for the specifics of each digitization activity.

2.7 Limitations of the Guidelines

These guidelines are specific to imaging to the four quality levels defined in this document, and these levels correspond to ISO standards. It is possible to digitize to higher than four-star specifications, which may be appropriate for specific applications that demand exceptional quality precision, for instance when attempting to identify small before/after treatment differences in conservation. Specifications for imaging projects that demand higher than four-star performance should be determined after considering the end use of the digital image and the original to be digitized.

The FADGI four-star system defines quality standards appropriate for most cultural heritage imaging projects, and takes into consideration the competing requirements of quality, speed of production, and cost. FADGI does not provide recommendations for applications that are either below one-star or above four-star requirements, nor do they form a how-to manual for achieving these ratings.

These guidelines do not address archiving/preservation of born-digital materials.

2.8 Resources

The FADGI website includes links to a variety of publications and other resources for digital imaging professionals. Please visit the page for these guidelines (https://digitizationguidelines.gov/guidelines/digitize-technical.html), the Technical Guidelines Resources page (https://www.digitizationguidelines.gov/guidelines/digitize-technical-resources.html), or the general FADGI Resources page (https://digitizationguidelines.gov/resources/).

2.9 Summary

By utilizing these guidelines and the information contained in this document, it is possible to have a cultural heritage imaging common language and to create industry-wide standardized output. These guidelines do not claim to be a how-to guide, because we recognize that there are often multiple methods for achieving a single outcome. Recommending a single method would stifle potential innovation in the field. The previous sections describe the requirements for the desired end result; the subsequent sections describe the specifics needed to achieve the various FADGI star ratings.

Chapter 3: Evaluation Criteria Values for Specific Material Types

3.1 Bound Volumes: Rare and Special Materials

Performance Level:	**1-Star**	**2-Star**	**3-Star**	**4-Star**
Master File Format		TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A
Access File Formats		All	All	All
Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)		≥ 242.5ppi (250 ppi – 3%)	≥ 294ppi (300 ppi – 2%)	≥ 396 ppi (400 ppi – 1%)
Bit Depth		8	8 or 16	16
Color Space		Adobe RGB (1998), ProPhoto, ECIRGB_v2	Adobe RGB (1998), ProPhoto, ECIRGB_v2	Adobe RGB (1998), ProPhoto, ECIRGB_v2
Color Mode		Color	Color	Color
Measurement Parameters				
Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch		≤ 4.5	≤ 3	≤ 1.5
Gain Modulation Highlight Patches (average L* between 95 and 85)		Gain between 0.6 and 1.3	Gain between 0.7 and 1.2	Gain between 0.8 and 1.1
Gain Modulation all other patches		Gain between 0.3 and 1.6	Gain between 0.6 and 1.4	Gain between 0.7 and 1.3
White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch		≤ 6	≤ 4	≤ 2
Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean L*)		≤ 5%	≤ 3%	≤ 1%
Average Color Accuracy (Units Colorimetric – Mean ΔE_{2000} – average deviation of all patches)		≤ 5	≤ 3.5	≤ 2
Color Accuracy 90^{th} Percentile (Units Colorimetric – ΔE_{2000} of all patches)		≤ 10	≤ 7	≤ 4

Color Channel Misregistration (Units Pixels)		≤ 0.8 pixel	≤ 0.5 pixel	≤ 0.33 pixel
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)		≥ 70%	≥ 80%	≥ 90%
SFR Response at Nyquist Frequency (Units Modulation)		< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]		Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)		<+/- 3%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)		< 1.1	< 1.05	≤ 1.02
Noise (Upper Limit) (Units Std Dev of L*)		≤ 3	≤ 2	≤ 1
Noise (Lower Limit) (Units Std Dev of L*) – A warning should be raised if the image doesn't meet this criteria		≥ 0.25	≥ 0.25	≥ 0.25

Note: The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

Bound Volumes: Rare and Special Materials

Rare and special bound materials represent various types ranging from illuminated manuscripts, incunabula, works that feature illustrations of special artistic or graphic interest (e.g., intaglios, gravures, or inset photographs); also bound documents with poor legibility or diffuse characters, e.g., carbon copies, Thermofax, etc.

Recommended Imaging Technologies

- Manually operated planetary book scanners with or without glass or plastic platens
- Digital cameras with book cradles with or without glass or plastic platens
- Automated page turning book scanners[2]

[2] There have been significant improvements in automated book scanning technology, and there are now commercially-available capture devices that are suitable for imaging some cultural heritage digitization projects. Organizations should evaluate the devices on the market to determine if they are appropriate for digitizing their collections. Do not use automatic book scanners that cause damage to collections materials.

Not Recommended Imaging Technologies

- Flatbed scanners
- Lighting systems that raise the surface temperature of the original more than 4 degrees F (2 degrees C) in the total imaging process
- Linear scanning processes (digital scanning back cameras) are not appropriate because of the potential for the original to flex during the scanning process, producing artifacts that cannot be corrected in post processing and that may not be seen in QC.
- Vacuum tables

Notes

- While other material categories include specifications for meeting one-star FADGI conformance, this is not appropriate for rare and special materials. One-star imaging is appropriate for applications where the intent is to provide a reference to locate the original or when there is no ability to image to a higher star level. Rare and special materials should be imaged at a high quality level in order to produce the best possible digital reproduction.
- To be FADGI compliant, all imaging performed on special collections materials must be done by personnel with advanced training and experienced in the handling and care of special collections materials. FADGI compliance requires proper staff qualifications in addition to achieving the performance levels defined in this document. It is out of the scope of this document to define proper staff qualifications for cultural heritage imaging.
- If a volume is dis-bound, the FADGI recommendations apply as if the volume was individual pages, capturing all edges of the page.
- Special collections materials will often contain colors that are outside of the gamut of current color reproduction systems, and will require special imaging techniques to approximate the original in digital form. Note that color accuracy is measured against the color test target, not the artifact.
- Alternative imaging techniques, including but not limited to texture lighting, multiple light source exposure, and multispectral/hyperspectral imaging may be used to best reproduce the original. These techniques should be accomplished as single exposures, not blends of multiple exposures. An “image cube” of multiple single exposures may be considered an archival master file, but a single base image must meet the specifications in the chart above for FADGI compliance in all respects.
- If a backing sheet is used, it must extend beyond the edge of the page to the end of the image on all open sides of the page.
- Collections materials should be maintained at the same temperature and humidity while being imaged as they are maintained in the collection.
- Special collections materials should not be placed in contact with glass or other materials in an effort to hold originals flat while imaging without appropriate approval and assistance. This technique can lead to physical damage to the original; this is particularly true for pigmented and gold leaf materials. Spatulas or other implements to assist in holding pages flat for imaging may be used, but must not obscure informational content. If used, these should not be edited out of master files.
- No image retouching is permitted to master files.
- Limited use of image processing techniques may be used for the creation of access files in FADGI.
- Bound materials must not be opened beyond the point where the binding is stressed. In some cases, that may mean that the volume cannot be opened sufficiently to image using traditional imaging technique.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.2 Bound Volumes: General Collections

Performance Level:	1-Star	2-Star	3-Star	4-Star
Master File Format	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A
Access File Formats	All	All	All	All
Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)	≥ 190ppi (200 ppi – 5%)	≥ 242.5ppi (250 ppi – 3%)	≥ 294ppi (300 ppi – 2%)	≥ 396 ppi (400 ppi – 1%)
Bit Depth	8	8	8 or 16	8 or 16
Color Space	Gray Gamma 2.2, sRGB	Gray Gamma 2.2, sRGB, Adobe RGB (1998), ProPhoto, ECIRGB_v2	Gray Gamma 2.2, sRGB, Adobe RGB (1998), ProPhoto, ECIRGB_v2	sRGB, Adobe RGB (1998), ProPhoto, ECIRGB_v2
Color Mode	Grayscale or Color	Grayscale or Color	Grayscale or Color	Color
Measurement Parameters				
Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch	≤ 6	≤ 4.5	≤ 3	≤ 1.5
Gain Modulation Highlight Patches (average L* between 95 and 85)	Gain between 0.5 and 1.4	Gain between 0.6 and 1.3	Gain between 0.7 and 1.2	Gain between 0.8 and 1.1
Gain Modulation all other patches	Gain between 0.25 and 1.7	Gain between 0.3 and 1.6	Gain between 0.6 and 1.4	Gain between 0.7 and 1.3
White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch	≤ 8	≤ 6	≤ 4	≤ 2

Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean L*)	≤ 8%	≤ 5%	≤ 3%	≤ 1%
Average Color Accuracy (Units Colorimetric – Mean ΔE_{2000} – average deviation of all patches)	≤ 6.5	≤ 5	≤ 3.5	≤ 2
Color Accuracy 90th Percentile (Units Colorimetric – ΔE_{2000} of all patches)	≤ 13	≤ 10	≤ 7	≤ 4
Color Channel Misregistration (Units Pixels)	≤ 1.2 pixel	≤ 0.8 pixel	≤ 0.5 pixel	≤ 0.33 pixel
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 60%	≥ 70%	≥ 80%	≥ 90%
SFR Response at Nyquist Frequency (Units Modulation)	< 0.5	< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>30%, <95%]	Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 5%	<+/- 3%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)	< 1.15	< 1.1	< 1.05	≤ 1.02
Noise (Upper Limit) (Units Std Dev of L*)	≤ 4	≤ 3	≤ 2	≤ 1

Noise (Lower Limit) (Units Std Dev of L*) – A warning should be raised if the image doesn't meet this criteria	≥ 0.25	≥ 0.25	≥ 0.25	≥ 0.25

Note: The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

Bound Volumes: General Collections

General collections bound materials span the range from new, clean and easy to handle materials to extremely brittle materials which may have poor legibility. Selection of appropriate digitization technology to efficiently digitize these materials is key to successful digitization.

Recommended Imaging Technologies

- Planetary book scanners with or without glass platens
- Digital cameras
- Auto page turning book scanners[3]

Not Recommended Imaging Technologies

- Flatbed scanners
- Lighting systems that raise the surface temperature of the original more than 6 degrees F (3 degrees C) in the total imaging process
- Linear scanning processes without glass or plastic platens (scanners and digital scanning back cameras) are not appropriate because of the potential for the original to flex during the scanning process, producing artifacts that cannot be corrected.

Notes

- If a volume is dis-bound, FADGI recommendations apply as if the volume was individual pages, capturing all edges of the page.
- If a book is "guillotined" for the purpose of scanning, it is no longer considered to be a book for the purposes of FADGI compliance. Refer to the section on document scanning.
- For master files, pages should be imaged to include the entire text block of the page. The digital image should capture as far into the gutter as practical but must include all of the content that is visible to the eye.
- If a backing sheet is used, it must extend to the end of the text block on all open sides of the page.
- Collections materials should be maintained at the same temperature and humidity while being imaged as they are maintained in the collection.
- No image retouching is permitted to master files.
- Books may be imaged in contact with glass or other materials in an effort to hold originals flat while imaging. However, the binding of the book must not be stressed in the process. The use of

[3] There have been significant improvements in automated book scanning technology, and there are now commercially-available capture devices that are suitable for imaging some cultural heritage digitization projects. Organizations should evaluate the devices on the market to determine if they are appropriate for digitizing their collections. Do not use automatic book scanners that cause damage to collections materials.

spatulas or other implements to assist in holding pages flat for imaging is approved, but must not obscure any informational content. If used, these must not be removed in master files.

- Bound materials must not be opened beyond the point where the binding is stressed. In some cases, that may mean that the volume cannot be opened sufficiently to image with traditional imaging techniques.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.3 Documents (Unbound): Manuscripts and Other Rare and Special Materials

Performance Level:	**1-Star**	**2-Star**	**3-Star**	**4-Star**
Master File Format		TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A
Access File Formats		All	All	All
Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)		≥ 242.5ppi (250 ppi – 3%)	≥ 294ppi (300 ppi – 2%)	≥ 396 ppi (400 ppi – 1%)
Bit Depth		8	8 or 16	16
Color Space		Adobe RGB (1998), ProPhoto, ECIRGB_v2	Adobe RGB (1998), ProPhoto, ECIRGB_v2	Adobe RGB (1998), ProPhoto, ECIRGB_v2
Color Mode		Color	Color	Color
Measurement Parameters				
Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}^{*}) for any given gray patch		≤ 4.5	≤ 3	≤ 1.5
Gain Modulation Highlight Patches (average L* between 95 and 85)		Gain between 0.6 and 1.3	Gain between 0.7 and 1.2	Gain between 0.8 and 1.1
Gain Modulation all other patches		Gain between 0.3 and 1.6	Gain between 0.6 and 1.4	Gain between 0.7 and 1.3
White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch		≤ 6	≤ 4	≤ 2
Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean L*)		≤ 5%	≤ 3%	≤ 1%

Average Color Accuracy (Units Colorimetric – Mean ΔE_{2000} – average deviation of all patches)		≤ 5	≤ 3.5	≤ 2
Color Accuracy 90th Percentile (Units Colorimetric – ΔE_{2000} of all patches)		≤ 10	≤ 7	≤ 4
Color Channel Misregistration (Units Pixels)		≤ 0.8 pixel	≤ 0.5 pixel	≤ 0.33 pixel
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)		≥ 70%	≥ 80%	≥ 90%
SFR Response at Nyquist Frequency (Units Modulation)		< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]		Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)		<+/- 3%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)		< 1.1	< 1.05	≤ 1.02
Noise (Upper Limit) (Units Std Dev of L*)		≤ 3	≤ 2	≤ 1
Noise (Lower Limit) (Units Std Dev of L*) – A warning should be raised if the image doesn't meet this criteria		≥ 0.25	≥ 0.25	≥ 0.25

Note: The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

Documents (Unbound): Manuscripts and Other Rare and Special Materials

Rare and special materials represent manuscripts, illustrations of special artistic or graphic interest; also documents with poor legibility or diffuse characters, e.g., carbon copies, Thermofax, etc.

Recommended Technologies

- Planetary scanners – manually operated
- Digital cameras

Not Recommended Technologies

- Lighting systems that raise the surface temperature of the original more than 4 degrees F (2 degrees C) in the total imaging process.
- Sheet fed scanning systems

Notes

- While other material categories include specifications for meeting one-star FADGI conformance, this is not appropriate for rare and special materials. One-star imaging is appropriate for applications where the intent is to provide a reference to locate the original or when there is no ability to image to a higher star level. Rare and special materials should be imaged at a high quality level in order to produce the best possible digital reproduction.
- To be FADGI compliant, all imaging performed on special collections materials must be done by personnel with advanced training and experienced in the handling and care of special collections materials. FADGI compliance requires proper staff qualifications in addition to achieving the performance levels defined in this document. It is out of the scope of this document to define proper staff qualifications for cultural heritage imaging.
- Special collections materials will often contain colors that are outside of the gamut of current color reproduction systems and will require special imaging techniques to approximate the original in digital form. Note that color accuracy is measured against the color test target, not the artifact.
- Alternative imaging techniques, including but not limited to texture lighting, multiple light source exposure, and multispectral/hyperspectral imaging may be used to best reproduce the original. These techniques should be accomplished as single exposures, not blends of multiple exposures. An “image cube” of multiple single exposures may be considered an archival master file, but a single base image must meet the specifications in the chart above for FADGI compliance in all respects.
- If a backing sheet is used, it must extend beyond the edge of the page to the end of the image on all sides of the page.
- Collections materials should be maintained at the same temperature and humidity while being imaged as they are maintained in the collection.
- Single exposure total area capture systems are considered the most appropriate technologies when imaging special collections materials. However, FADGI permits the use of other technologies that may be appropriate as long as none of the stated restrictions are compromised by the use of that technology.
- Special collections materials should not be placed in contact with glass or other materials in an effort to hold originals flat while imaging, without the approval of a paper or book conservator. This technique can lead to physical damage to the original. Spatulas or other implements to assist in holding pages flat for imaging may be used, but must not obscure informational content. If used, these should not be edited out of master files.
- Holding down an original with the use of a vacuum board should also be approved by a paper or book conservator. Air forced through the original over the vacuum ports can permanently degrade some originals.
- No image retouching is permitted to master files.
- Image processing techniques are approved for the creation of access files in FADGI.

- For master files, documents should be imaged to include the entire area and a small amount beyond to define the area. Access files may be cropped.
- Image capture resolutions above 400 ppi may be appropriate for some materials, but imaging at higher resolutions is not required to achieve 4* compliance.
- Single exposure total area capture scanning systems are considered the most appropriate technologies when imaging special collections materials, including documents. However, FADGI permits the use of other technologies that may be appropriate as long as none of the stated restrictions are compromised by the use of that technology.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.4 Documents (Unbound): General Collections

Performance Level:	1-Star	2-Star	3-Star	4-Star
Master File Format	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A
Access File Formats	All	All	All	All
Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)	≥ 190ppi (200 ppi – 5%)	≥ 242.5ppi (250 ppi – 3%)	≥ 294ppi (300 ppi – 2%)	≥ 396 ppi (400 ppi – 1%)
Bit Depth	8	8	8 or 16	16
Color Space	Gray Gamma 2.2, sRGB	Adobe RGB (1998), sRGB, ProPhoto, ECIRGB_v2	Adobe RGB (1998), sRGB, ProPhoto, ECIRGB_v2	Adobe RGB (1998), sRGB, ProPhoto, ECIRGB_v2
Color Mode	Grayscale or Color	Color	Color	Color
Measurement Parameters				
Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch	≤ 6	≤ 4.5	≤ 3	≤ 1.5
Gain Modulation Highlight Patches (average L* between 95 and 85)	Gain between 0.5 and 1.4	Gain between 0.6 and 1.3	Gain between 0.7 and 1.2	Gain between 0.8 and 1.1
Gain Modulation all other patches	Gain between 0.25 and 1.7	Gain between 0.3 and 1.6	Gain between 0.6 and 1.4	Gain between 0.7 and 1.3
White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch	≤ 8	≤ 6	≤ 4	≤ 2
Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean L*)	≤ 8%	≤ 5%	≤ 3%	≤ 1%

Average Color Accuracy (Units Colorimetric – Mean ΔE_{2000} – average deviation of all patches)	≤ 6.5	≤ 5	≤ 3.5	≤ 2
Color Accuracy 90^{th} Percentile (Units Colorimetric – ΔE_{2000} of all patches)	≤ 13	≤ 10	≤ 7	≤ 4
Color Channel Misregistration (Units Pixels)	≤ 1.2 pixel	≤ 0.8 pixel	≤ 0.5 pixel	≤ 0.33 pixel
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 60%	≥ 70%	≥ 80%	≥ 90%
SFR Response at Nyquist Frequency (Units Modulation)	< 0.5	< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>30%, <95%]	Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 5%	<+/- 3%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)	< 1.15	< 1.1	< 1.05	≤ 1.02
Noise (Upper Limit) (Units Std Dev of L*)	≤ 4	≤ 3	≤ 2	≤ 1
Noise (Lower Limit) (Units Std Dev of L*) – A warning should be raised if the image doesn't meet this criteria	≥ 0.25	≥ 0.25	≥ 0.25	≥ 0.25

Note: The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

Documents (Unbound): General Collections

General collections unbound materials span the range from new, clean and easy to handle materials to extremely brittle materials which may have poor legibility. Selection of appropriate digitization technology to efficiently digitize these materials is key to successful digitization.

Recommended Technologies

- Planetary scanners with or without glass platens
- Digital cameras
- Flatbed scanners

Not Recommended Technologies

- Lighting systems that raise the surface temperature of the original more than 6 degrees F (3 degrees C) in the total imaging process
- Pass through manual or automatically fed document scanners. This class of equipment often introduces streak artifacts in the imaging process, which are not FADGI compliant.

Notes

- For master files, documents should be imaged to include the entire area of the page and a small amount beyond to define the page area.
- Care must be taken to use an appropriate solid backing color when imaging documents if needed. Any color may be used as appropriate, but if used must extend beyond the original on all sides.
- Image capture resolutions above 400 ppi may be appropriate for some materials, but imaging at higher resolutions is not required to achieve 4 star compliance.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.5 Documents (Unbound): Modern Textual Records

Master File Format Name and Version	Acceptable Compression Codecs
TIFF 6.0	Uncompressed, DEFLATE (ZIP)
JPEG2000 part 1 (ISO/IEC 15444-1:2019)	JPEG 2000 part 1 core coding system lossless compression. Federal agencies may use up to 20:1 visually lossless compression.
Portable network graphics 1.2 (PNG)	DEFLATE (ZIP)
PDF/A	DEFLATE (ZIP), JPEG 2000 part 1 core coding system lossless compression. Federal agencies may use up to 20:1 visually lossless compression.
Measurement Parameters	
Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)	≥ 294ppi (300 ppi – 2%)
Bit Depth	8 or 16
Color Space	Gray Gamma 2.2, Adobe RGB (1998), sRGB, ProPhoto, ECIRGB_v2
Color Mode	Color or grayscale
Measurement Parameters	Performance metric values Difference from aim (applies to 20 ≤ L* ≤ 100)
Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for gray patches that meet the measurement parameters	≤ 3
White Balance (Units Colorimetric ΔE(a*b*)) for gray patches that meet the measurement parameters	≤ 4
Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean L*)	≤ 3%
Average Color Accuracy (Units Colorimetric – Mean ΔE_{2000} – average deviation for patches meeting measurement parameters)	≤ 3.5

Color Accuracy 90^{th} Percentile (Units Colorimetric – ΔE_{2000} for patches meeting measurement parameters)	≤ 7
Color Channel Misregistration (Units Pixels)	≤ 0.5 pixel
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 80%
SFR50 (50% SFR) (Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>40%, <75%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 2%
Sharpening (Units Max Modulation)	< 1.05
Noise (Upper Limit) (Units Std Dev of L*)	≤ 2
Noise (Lower Limit) (Units Std Dev of L*) – A warning should be raised if the image doesn't meet this criteria	≥ 0.25

Note: The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level.

Modern Textual Records

Textual records generally refer to documents created on modern office paper. Records suitable for this category are paper records with well-defined printed type (such as typeset, typed, laser-printed, etc.), and with moderate to high contrast between the ink of the text and the paper background. This is a new category and specifications as proposed by the National Archives and Records Administration.

In general, most modern textual documents do not have neutral content with L* values darker than 20. Therefore, any neutral components on the evaluation test target with L* less than 20 should not be used for analysis. This will impact three metrics – OECF, Noise, and White Balance – when using digital image conformance evaluation test patterns. The specifications in this table are applicable when the original source paper records do not have recordable information. The equipment used to digitize modern textual records must be appropriate for the media type, meet the file format, digital file specifications, and the performance evaluation parameters specified in this table.

The specifications in this table are not applicable for paper records that include fine detail, require a high degree of color or tonal accuracy, or have other unique characteristics that cannot be captured using the specifications in this table. For this category there are no star levels; either the images meet the specifications above or they do not. When using JPEG 2000 visually lossless compression, agencies must determine the amount of compression to apply, not to exceed 20:1, by performing tests and visually evaluating for compression artifacts that obscure or alter the information content.

Recommended Technologies

- Planetary scanners with or without glass platens
- Digital cameras
- Pass through manual or automatic document feeder (ADF or sheetfed) scanners
- Flatbed scanners

Not Recommended Technologies

- Lighting systems that raise the surface temperature of the original more than 6 degrees F (3 degrees C) in the total imaging process

Notes

The specifications in this section are the minimum requirements to meet the National Archives and Records Administration's proposed regulations for the digitization of permanent federal records. Depending on the characteristics of the original source records, agencies must select the applicable specifications to ensure that all information is captured. For paper records that have visible content in the L* values darker than 20, users must at a minimum select criteria to meet FADGI 3* Documents (Unbound): General Collections. Agencies may exceed any of the specifications in these tables if necessary to capture all of the information in a record.

3.6 Oversize Items: Maps, Posters, and Other Materials

Performance Level:	1-Star	2-Star	3-Star	4-Star
Master File Format	TIFF, JPEG 2000	TIFF, JPEG 2000	TIFF, JPEG 2000	TIFF, JPEG 2000
Access File Formats	All	All	All	All
Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)	≥ 190ppi (200 ppi – 3%)	≥ 242.5ppi (250 ppi – 2.5%)	≥ 294ppi (300 ppi – 2%)	≥ 396ppi (400 ppi – 1%)
Bit Depth	8	8	8 or 16	8 or 16
Color Space	Gray Gamma 2.2, sRGB	Gray Gamma 2.2, sRGB, Adobe RGB (1998), ProPhoto, ECIRGB_v2	Gray Gamma 2.2, sRGB, Adobe RGB (1998), ProPhoto, ECIRGB_v2	Gray Gamma 2.2, sRGB, Adobe RGB (1998), ProPhoto, ECIRGB_v2
Color Mode	Grayscale or Color	Grayscale or Color	Grayscale or Color	Grayscale or Color
Measurement Parameters				
Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch	< 6	< 4.5	< 3	< 1.5
Gain Modulation Highlight Patches (average L* between 95 and 85)	Gain between 0.5 and 1.4	Gain between 0.6 and 1.3	Gain between 0.7 and 1.2	Gain between 0.8 and 1.1
Gain Modulation all other patches	Gain between 0.25 and 1.7	Gain between 0.3 and 1.6	Gain between 0.6 and 1.4	Gain between 0.7 and 1.3
White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch	< 8	< 6	< 4	< 2
Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean L*)	< 8%	< 5%	< 3%	< 1%

Average Color Accuracy (Units Colorimetric – Mean ΔE_{2000} – average deviation of all patches)	≤ 6.5	≤ 5	≤ 3.5	≤ 2
Color Accuracy 90^{th} Percentile (Units Colorimetric – ΔE_{2000} of all patches)	≤ 13	≤ 10	≤ 7	≤ 4
Color Channel Misregistration (Units Pixels)	≤ 1.2 pixel	≤ 0.8 pixel	≤ 0.5 pixel	≤ 0.33 pixel
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 60%	≥ 70%	≥ 80%	≥ 90%
SFR Response at Nyquist Frequency (Units Modulation)	< 0.5	< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>30%, <95%]	Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 3%	<+/- 2.5%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)	< 1.15	< 1.1	< 1.05	≤ 1.02
Noise (Upper Limit) (Units Std Dev of L*)	≤ 4	≤ 3	≤ 2	≤ 1
Noise (Lower Limit) (Units Std Dev of L*) – A warning should be raised if the image doesn't meet this criteria	≥ 0.25	≥ 0.25	≥ 0.25	≥ 0.25

Gray Gamma 2.2 color space is only appropriate for monochrome originals.

Note: The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

Oversize Items: Maps, Posters, and Other Materials with Challenging Features That Will Benefit from High Resolution Reproduction

Recommended Technologies

- Planetary scanners
- Digital cameras
- Flatbed scanners

Not Recommended Technologies

- Pass through manual or automatically fed document scanners. This class of equipment often introduces streak artifacts in the imaging process, which are not FADGI compliant.
- Lighting systems that raise the surface temperature of the original more than 4 degrees F (2 degrees C) in the total imaging process

There are three basic methods used in scanning large format materials, all of which have limitations. The first involves capturing the whole original in a single capture. Using the best sensors and lenses, this approach can provide high quality results for relatively small originals, but is inadequate for larger originals.

The second approach involves using a linear scanning system which acquires the image one line at a time, assembling the final image from these lines of image data in sequence. This approach can deliver higher resolution images than the first approach, but is limited by the size of the sensor and/or available lenses.

The third approach involves capturing the image in small sections or tiles, and stitching the tiles together to form the final image using specialized software. This approach has no limitation to resolution or original size, and is only limited by the file size limit of the master file format. Care must be taken to assure that the images captured in each of the tiles are identical in all respects to allow proper stitching and image reassembly. However, this approach suffers from the loss of geometric accuracy and resolution inherent in acquiring images in sections and stitching them into a single image.

In all three approaches, geometric accuracy can vary dramatically based on the approach taken and the specific imaging systems used. All three can produce highly accurate images, and all three can deliver poor accuracy. FADGI does not endorse any one of these approaches over another. Each has their appropriate use.

Notes

- For master files, documents should be imaged to include the entire area of the original and a small amount beyond to define the area.
- Care must be taken to use an appropriate solid backing color when imaging, if needed. Any color may be used as appropriate, but if used must extend beyond the original. The backing material should not be used to set the tonal range or analyzed as a part of the tonal response.
- Image capture resolutions above 400 ppi may be appropriate for some materials, and should be considered as appropriate to the original being imaged. Very fine detailed engravings, for example, may require 800 ppi or higher to image properly.
- Large originals at high ppi resolutions will exceed the maximum file size allowed in the TIFF format. If necessary, saving the master file as a tile set is appropriate.
- If the image capture is made in sections, the files must be related by file naming and embedded metadata. As the group of files as a whole is considered the archival master file, a folder containing all files should be retained for archival purposes.
- If the sections of a multiple scan item are compiled into a single image, the combined image is considered the production master.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.7 Newspapers

Performance Level:	1-Star	2-Star	3-Star	4-Star
Master File Format	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A	TIFF, JPEG 2000, PDF/A
Access File Formats	All	All	All	All
Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)	≥190ppi (200 ppi – 5%)	≥ 242.5ppi (250 ppi – 3%)	≥ 294ppi (300 ppi – 2%)	≥ 396 ppi (400 ppi – 1%)
Bit Depth	8	8	8	8
Color Space	Gray Gamma 2.2, sRGB	Gray Gamma 2.2, sRGB	Gray Gamma 2.2, sRGB	Gray Gamma 2.2, sRGB
Color Mode	Grayscale or Color	Grayscale or Color	Grayscale or Color	Color
Measurement Parameters				
Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch	≤ 6	≤ 4.5	≤ 3	≤ 1.5
Gain Modulation Highlight Patches (average L* between 95 and 85)	Gain between 0.5 and 1.4	Gain between 0.6 and 1.3	Gain between 0.7 and 1.2	Gain between 0.8 and 1.1
Gain Modulation all other patches	Gain between 0.25 and 1.7	Gain between 0.3 and 1.6	Gain between 0.6 and 1.4	Gain between 0.7 and 1.3
White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch	≤ 8	≤ 6	≤ 4	≤ 2
Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean)	≤ 8%	≤ 5%	≤ 3%	≤ 1%

Average Color Accuracy (Units Colorimetric – Mean ΔE_{2000} – average deviation of all patches)	≤ 6.5	≤ 5	≤ 3.5	≤ 2
Color Accuracy 90th Percentile (Units Colorimetric – ΔE_{2000} of all patches)	≤ 13	≤ 10	≤ 7	≤ 4
Color Channel Misregistration (Units Pixels)	≤ 1.2 pixel	≤ 0.8 pixel	≤ 0.5 pixel	≤ 0.33 pixel
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 60%	≥ 70%	≥ 80%	≥ 90%
SFR Response at Nyquist Frequency (Units Modulation)	< 0.5	< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>30%, <95%]	Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 5%	<+/- 3%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)	< 1.15	< 1.1	< 1.05	≤ 1.02
Noise (Upper Limit) (Units Std Dev of L*)	≤ 4	≤ 3	≤ 2	≤ 1
Noise (Lower Limit) (Units Std Dev of L*) – A warning should be raised if the image doesn't meet this criteria	≥ 0.25	≥ 0.25	≥ 0.25	≥ 0.25

Note: The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

Newspapers

Recommended Technologies

- Planetary scanners
- Digital cameras
- Flatbed scanners
- Sheet fed scanners

Not Recommended Technologies

- None

Three-star performance specifications are recommended for newspaper digitization. This performance level has been tested with OCR and found to provide excellent results with a variety of languages and conditions of the newspaper.

JPEG 2000 is recommended as a master format, using lossy compression. The following settings have been tested and found to be optimal:

Compression rate: 20 (maximum)

Quality layer: 1

Reduction level: 8

Tile size: full image size

Progression order: RLCP

Newspaper digitization spans the range from extremely fragile documents to modern paper which can be handled easily when new, but ages quickly. The specific techniques needed to successfully digitize newspapers will vary with the collections and the institutions. Fragile newspapers should only be imaged on scanners that do not stress the paper. Modern newspapers may be suitable for scanning through pass through scanners.

Newspaper digitization is a unique application best done using dedicated hardware and software systems designed specifically for newspaper digitization.

Notes

- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.8 Prints and Photographs

Performance Level:	1-Star	2-Star	3-Star	4-Star
Master File Format	TIFF, JPEG 2000	TIFF, JPEG 2000	TIFF, JPEG 2000	TIFF, JPEG 2000
Access File Formats	All	All	All	All
Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)	≥ 194ppi (200 ppi – 3%)	≥ 243.75ppi (250ppi – 2.5%)	≥ 392ppi (400 ppi – 2%)	≥ 594 ppi[4] (600 ppi – 1%)
Bit Depth	8	8	8 or 16	16
Color Space	Gray Gamma 2.2, sRGB, Adobe RGB (1998), ProPhoto, ECIRGB_v2	Gray Gamma 2.2, sRGB, Adobe RGB (1998), ProPhoto, ECIRGB_v2	Adobe RGB (1998), ProPhoto, ECIRGB_v2	Adobe RGB (1998), ProPhoto, ECIRGB_v2
Color Mode	Grayscale or Color	Grayscale or Color	Color	Color
Measurement Parameters				
Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch	≤ 6	≤ 4.5	≤ 3	≤ 1.5
Gain Modulation Highlight Patches (average L* between 95 and 85)	Gain between 0.5 and 1.4	Gain between 0.6 and 1.3	Gain between 0.7 and 1.2	Gain between 0.8 and 1.1
Gain Modulation all other patches	Gain between 0.25 and 1.7	Gain between 0.3 and 1.6	Gain between 0.6 and 1.4	Gain between 0.7 and 1.3
White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch	≤ 8	≤ 6	≤ 4	≤ 2
Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean)	≤ 8%	≤ 5%	≤ 3%	≤ 1%

[4] In rare cases, resolutions higher than 600 ppi may be needed to resolve fine details.

Average Color Accuracy (Units Colorimetric – Mean ΔE_{2000} – average deviation of all patches)	≤ 6.5	≤ 5	≤ 3.5	≤ 2
Color Accuracy 90^{th} Percentile (Units Colorimetric – ΔE_{2000} of all patches)	≤ 13	≤ 10	≤ 7	≤ 4
Color Channel Misregistration (Units Pixels)	≤ 1.2 pixel	≤ 0.8 pixel	≤ 0.5 pixel	≤ 0.33 pixel
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 60%	≥ 70%	≥ 80%	≥ 90%
SFR Response at Nyquist Frequency (Units Modulation)	< 0.5	< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>30%, <95%]	Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 3%	<+/- 2.5%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)	< 1.15	< 1.1	< 1.05	≤ 1.02
Noise (Upper Limit) (Units Std Dev of L*)	≤ 4	≤ 3	≤ 2	≤ 1
Noise (Lower Limit) (Units Std Dev of L*) – A warning should be raised if the image doesn't meet this criteria	≥ 0.25	≥ 0.25	≥ 0.25	≥ 0.25

Note: The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

Prints and Photographs

Includes photographic prints, graphic-arts prints (intaglio, lithographs, etc.), drawings, some paintings, (e.g., water colors), and some maps.

Recommended Technologies

- Planetary scanners
- Digital cameras
- Flatbed scanners

Not Recommended Technologies

- Drum scanners
- Lighting systems that raise the surface temperature of the original more than 4 degrees F (2 degrees C) in the total imaging process

The intent in scanning photographs is to maintain the smallest significant details. Resolution requirements for photographs are often difficult to determine because there is no obvious fixed metric for measuring detail such as quality index. Additionally, accurate tone and color reproduction in the scan play an equal, if not more, important role in assessing the quality of a scan of a photograph.

The recommended scanning specifications for photographs take into account the intended uses of the four star levels. For photographic formats in particular, it is important to carefully analyze the material prior to scanning. Because every generation of photographic copying involves some quality loss, using intermediates, duplicates, or copies inherently implies some decrease in quality and may also be accompanied by other problems (such as improper orientation, low or high contrast, uneven lighting, etc.).

Notes

- "Prints and Photographs" encompass a wide range of technologies and processes that have been used to create reflective images. For many of these, subtle texture, tone and color differences are an essential part of their character. While it is not possible to preserve all of these subtle physical differences in digital form, we can approximate some of their unique qualities. It is for this reason that all master files from both color and black and white originals are to be imaged in 16-bit color at or above 3-star performance.
- The use of glass or other materials to hold an image flat during capture is allowed, but only when the original will not be harmed by doing so. Care must be taken to assure that flattening a photograph will not result in emulsion cracking, or the base material being damaged. Tightly curled materials must not be forced to lay flat. It is highly recommended to use anti-reflective glass if the decision is made to use glass. The special coatings on this type of glass dramatically reduce reflected glare and interference patterns (Newton's rings).
- There are a variety of visible degradations that occur with photographs, many of which can be minimized using special imaging techniques. The application and use of these techniques are beyond the scope of this document but can be found in contemporary photography literature. Alternate imaging techniques are approved for FADGI imaging. The use of these techniques can result in multiple images of the same photograph. These images must be referenced as a group in file naming and embedded metadata. The group of files is considered the master image.
- If alternate lighting techniques are used and the resulting master file is a single image, the alternate imaging technique must conform to the FADGI specifications. If using alternate imaging techniques results in multiple files of the same original, one of the images must conform to the FADGI specifications, and this image must be identified as the base.
- FADGI allows the use of flatbed scanners when imaging photographs, but the user should be aware that images may render differently on a flatbed scanner than if imaged using a camera or planetary scanner and traditional copy lighting. Additionally, when using a flatbed scanner, dust and dirt on the scanner glass and optical system can result in dust and dirt in the file.
- Dust removal is not allowed on master images, and digital dust removal techniques during the scanning process are also not approved.

- Color, tone enhancement or restoration is not allowed on master images.
- Photographic print processes vary widely in their response to digital sensors. A reference target should be imaged with each exposure and retained in the master file. Color and tone adjustments must be made to the target data, not the photograph.
- Adjustments to correct or enhance the image may be made to access versions, and noted as such in embedded metadata and file naming.
- Imaging using devices without RGB color filter arrays (monochrome) for black and white materials has been shown to significantly improve image quality. However, if the tone of the original is important to preserve, this approach may be inappropriate.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.9 Photographic Transparencies: 35mm up to 4”x5”

<table>
<tr><th colspan="2">Performance Level:</th><th>1-Star</th><th>2-Star</th><th>3-Star</th><th>4-Star</th></tr>
<tr><td colspan="2">Master File Format</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td></tr>
<tr><td colspan="2">Access File Formats</td><td>All</td><td>All</td><td>All</td><td>All</td></tr>
<tr><td colspan="2">Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)</td><td>≥ 970 ppi
(1000 ppi – 3%)</td><td>≥ 1950 ppi
(2000 ppi – 2.5%)</td><td>≥ 2940 ppi
(3000 ppi – 2%)</td><td>≥ 3960 ppi
(4000 ppi – 1%)</td></tr>
<tr><td colspan="2">Bit Depth</td><td>8</td><td>8</td><td>16</td><td>16</td></tr>
<tr><td colspan="2">Color Space</td><td>Gray Gamma 2.2,
sRGB,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2,
sRGB,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td></tr>
<tr><td colspan="2">Color Mode</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td></tr>
<tr><th colspan="6">Measurement Parameters</th></tr>
<tr><td colspan="2">*Highlight/Shadow, Tolerance (Units Colorimetric)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td></tr>
<tr><td colspan="2">*Dynamic Range (D max minus D min)</td><td>3.5</td><td>3.8</td><td>3.9</td><td>4.0</td></tr>
<tr><td rowspan="3">◇ Provisional</td><td>Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch</td><td>≤ 5.25</td><td>≤ 4.0</td><td>≤ 2.75</td><td>≤ 1.5</td></tr>
<tr><td>White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch</td><td>≤ 5.25</td><td>≤ 4.0</td><td>≤ 2.75</td><td>≤ 1.5</td></tr>
<tr><td>Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean)</td><td>≤ 8%</td><td>≤ 5%</td><td>≤ 3%</td><td>≤ 1%</td></tr>
<tr><td colspan="2">Color Channel
Misregistration (Units Pixels)</td><td>≤ 1.2 pixel</td><td>≤ 0.8 pixel</td><td>≤ 0.5 pixel</td><td>≤ 0.33 pixel</td></tr>
</table>

SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 60%	≥ 70%	≥ 80%	≥ 90%
*SFR Response at Nyquist Frequency (Units Modulation)	< 0.5	< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>30%, <95%]	Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 3%	<+/- 2.5%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)	< 1.15	< 1.1	< 1.05	≤ 1.02

Note: *The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

◊ Unlike the reflection content addressed in most of these guidelines, film content is generally not considered ‘scene referred’ since the film image is one or several generations removed from the original captured scene. The original content by which to judge colorimetric goodness is therefore ambiguous. Nevertheless, some aim response and consistency measure (tolerances) are still required for well-behaved captures. The values cited here have been studied and compared against optical density equivalents up to a density of 2.2 and are considered reasonable values by experts in the field. Until there is evidence to the contrary these values should be adopted provisionally.

Photographic Transparencies: 35mm up to 4”x5”

Black-and-white or color (positive) transparencies that can be captured without the need for post-capture assembly of tiles to produce a complete image.

Recommended Technologies

- Film scanners
- Planetary scanners
- Digital cameras
- Flatbed scanners

Not Recommended Technologies

- Drum scanners

Notes

- Transparency films can have a d-max approaching 4.0. Additionally, this high d-max may be adjacent to d-min areas of about .05 density. This wide density range challenges the best optics and the best imaging sensors. The lack of dynamic range in a scanning system will result in poor highlight and shadow detail and poor color reproduction. Lens flare will reduce the purity of color reproduction and distort the tonality of an image. Very high quality lenses designed for specific reproduction ratios will reduce flare and improve SFR. Working in a dimly lit environment will reduce the effect of ambient light on the image capture.
- Dynamic Range is an informative metric, and not critical for evaluating whether an image is FADGI-compliant. As such the row for this metric is shaded differently than the critical metrics in the table above.

- Appropriate lens selection for film scanning is critical. Lenses designed for general imaging are not appropriate for close focusing film scanning applications. Lenses must be of a flat field design and have the ability to focus all colors at the same plane (apochromatic).
- Sufficient illumination intensity must be available to image at the best performance level for the imaging system. The optimum aperture should be determined through testing, and is generally one to two f stops from maximum aperture. Exposure time should be short enough to eliminate the possibility of vibration affecting resolution, and room illumination degrading the image.
- Profiling a scanner will not assure FADGI compliance or accurate color reproduction. Profiling can only work with the image as it was captured. Profiling cannot restore color or detail that was lost in the digital capture process. Films should be profiled with the closest available Q60-IT8 target. The best workflow may be to capture raw, adjust in a calibrated environment, and tag the corrected file with the appropriate color profile.
- Kodachrome films cannot be profiled correctly using an Ektachrome IT-8 target. Kodachrome it8 targets are very rare, but almost essential for the proper digitization of Kodachrome films. Obtaining a professionally produced Kodachrome ICC profile is perhaps the best solution to this issue.
- For original color transparencies, the tonal scale and color balance of the digital image should match the original transparency being scanned to provide accurate representation of the image.
- The use of a 5000k light box and a calibrated viewing environment is critical.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.10 Photographic Transparencies 4” x 5” and Larger

<table>
<tr><th colspan="2">Performance Level:</th><th>1-Star</th><th>2-Star</th><th>3-Star</th><th>4-Star</th></tr>
<tr><td colspan="2">Master File Format</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td></tr>
<tr><td colspan="2">Access File Formats</td><td>All</td><td>All</td><td>All</td><td>All</td></tr>
<tr><td colspan="2">Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)[5]</td><td>≥ 485 ppi
(500 ppi – 3%)</td><td>≥ 975 ppi
(1000 ppi – 2.5%)</td><td>≥ 1470 ppi
(1500 ppi – 2%)</td><td>≥ 1980 ppi
(2000 ppi – 1%)</td></tr>
<tr><td colspan="2">Bit Depth</td><td>8</td><td>8</td><td>16</td><td>16</td></tr>
<tr><td colspan="2">Color Space</td><td>Gray Gamma 2.2,
sRGB,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2,
sRGB,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td></tr>
<tr><td colspan="2">Color Mode</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td></tr>
<tr><th colspan="6">Measurement Parameters</th></tr>
<tr><td colspan="2">*Highlight/Shadow, Tolerance (Units Colorimetric)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td></tr>
<tr><td colspan="2">*Dynamic Range (D max minus D min)</td><td>3.5</td><td>3.8</td><td>3.9</td><td>4.0</td></tr>
<tr><td rowspan="3">◇ Provisional</td><td>Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch</td><td>≤ 5.25</td><td>≤ 4.0</td><td>≤ 2.75</td><td>≤ 1.5</td></tr>
<tr><td>White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch</td><td>≤ 5.25</td><td>≤ 4.0</td><td>≤ 2.75</td><td>≤ 1.5</td></tr>
<tr><td>Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean)</td><td>≤ 8%</td><td>≤ 5%</td><td>≤ 3%</td><td>≤ 1%</td></tr>
</table>

[5] Large format films may have actual resolutions that exceed this specification, but imaging at higher resolutions may exceed practical file sizes.

Color Channel Misregistration (Units Pixels)	≤ 1.2 pixel	≤ 0.8 pixel	≤ 0.5 pixel	≤ 0.33 pixel
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 60%	≥ 70%	≥ 80%	≥ 90%
*SFR Response at Nyquist Frequency (Units Modulation)	< 0.5	< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>30%, <95%]	Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 3%	<+/- 2.5%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)	< 1.15	< 1.1	< 1.05	≤ 1.02

Note: *The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

◊ Unlike the reflection content addressed in most of these guidelines, film content is generally not considered ‘scene referred’ since the film image is one or several generations removed from the original captured scene. The original content by which to judge colorimetric goodness is therefore ambiguous. Nevertheless, some aim response and consistency measure (tolerances) are still required for well-behaved captures. The values cited here have been studied and compared against optical density equivalents up to a density of 2.2 and are considered reasonable values by experts in the field. Until there is evidence to the contrary these values should be adopted provisionally.

Photographic Transparencies 4” x 5” and Larger

Black-and-white or color (positive) transparencies that are likely to require post-capture assembly of tiles to produce a complete image.

Recommended Technologies

- Film scanners
- Planetary scanners
- Digital cameras
- Flatbed scanners

Not Recommended Technologies

- Drum scanners

Notes

- Transparency films can have a d-max approaching 4.0. Additionally, this high d-max may be adjacent to d-min areas of about .05 density. This wide density range challenges the best optics and the best imaging sensors. The lack of dynamic range in a scanning system will result in poor highlight and shadow detail and poor color reproduction. Lens flare will reduce the purity of color reproduction and distort the tonality of an image. Very high quality lenses designed for specific reproduction ratios will reduce flare and improve SFR. Working in a dimly lit environment will reduce the effect of ambient light on the image capture.

- Dynamic Range is an informative metric, and not critical for evaluating whether an image is FADGI-compliant. As such the row for this metric is shaded differently than the critical metrics in the table above.
- Appropriate lens selection for film scanning is critical. Lenses designed for general imaging are not appropriate for close focusing film scanning applications. Lenses must be of a flat field design and have the ability to focus all colors at the same plane (apochromatic).
- Sufficient illumination intensity must be available to image at the best performance level for the imaging system. The optimum aperture should be determined through testing, and is generally one to two f stops from maximum aperture. Exposure time should be short enough to eliminate the possibility of vibration affecting resolution.
- Profiling a scanner will not assure FADGI compliance or accurate color reproduction. Profiling can only work with the image as it was captured. Profiling cannot restore color or detail that was lost in the digital capture process. Films should be profiled with the closest available Q60-IT8 target. The best workflow may be to capture raw, adjust in a calibrated environment, and tag the corrected file with the appropriate color profile.
- For original color transparencies, the tonal scale and color balance of the digital image should match the original transparency being scanned to provide accurate representation of the image.
- The use of a 5000k light box, in a calibrated viewing environment is critical.
- It may be necessary to capture large format transparencies in multiple tiles and “stitch” the multiple images back together to capture all of the detail in an original transparency. If “stitching” is needed, the completed “stitched” file may be considered the production master, with the stitch elements considered the archival master file.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.11 Photographic Negatives: 35mm up to 4”x5”

<table>
<tr><th colspan="2">Performance Level:</th><th>1-Star</th><th>2-Star</th><th>3-Star</th><th>4-Star</th></tr>
<tr><td colspan="2">Master File Format</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td></tr>
<tr><td colspan="2">Access File Formats</td><td>All</td><td>All</td><td>All</td><td>All</td></tr>
<tr><td colspan="2">Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)</td><td>≥ 970 ppi
(1000 ppi – 3%)</td><td>≥ 1950 ppi
(2000 ppi – 2.5%)</td><td>≥ 2940 ppi
(3000 ppi – 2%)</td><td>≥ 3960 ppi
(4000 ppi – 1%)</td></tr>
<tr><td colspan="2">Bit Depth</td><td>8</td><td>8</td><td>16</td><td>16</td></tr>
<tr><td colspan="2">Color Space</td><td>Gray Gamma 2.2,
sRGB,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2
sRGB,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td></tr>
<tr><td colspan="2">Color Mode</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td></tr>
<tr><th colspan="6">Measurement Parameters</th></tr>
<tr><td colspan="2">*Highlight/Shadow, Tolerance (Units Colorimetric)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td></tr>
<tr><td colspan="2">*Dynamic Range (D max minus D min)</td><td>3.5</td><td>3.8</td><td>3.9</td><td>4.0</td></tr>
<tr><td rowspan="3">◇ Provisional</td><td>Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch</td><td>≤ 5.25</td><td>≤ 4.0</td><td>≤ 2.75</td><td>≤ 1.5</td></tr>
<tr><td>White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch</td><td>≤ 5.25</td><td>≤ 4.0</td><td>≤ 2.75</td><td>≤ 1.5</td></tr>
<tr><td>Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean)</td><td>≤ 8%</td><td>≤ 5%</td><td>≤ 3%</td><td>≤ 1%</td></tr>
<tr><td colspan="2">Color Channel
Misregistration (Units Pixels)</td><td>≤ 1.2 pixel</td><td>≤ 0.8 pixel</td><td>≤ 0.5 pixel</td><td>≤ 0.33 pixel</td></tr>
</table>

SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 60%	≥ 70%	≥ 80%	≥ 90%
*SFR Response at Nyquist Frequency (Units Modulation)	< 0.5	< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>30%, <95%]	Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 3%	<+/- 2.5%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)	< 1.15	< 1.1	< 1.05	≤ 1.02

Note: *The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

◊ Unlike the reflection content addressed in most of these guidelines, film content is generally not considered ‘scene referred’ since the film image is one or several generations removed from the original captured scene. The original content by which to judge colorimetric goodness is therefore ambiguous. Nevertheless, some aim response and consistency measure (tolerances) are still required for well-behaved captures. The values cited here have been studied and compared against optical density equivalents up to a density of 2.2 and are considered reasonable values by experts in the field. Until there is evidence to the contrary these values should be adopted provisionally.

Photographic Negatives 35mm up to 4”x5”

Black-and white or color negatives that can be captured without need for post capture assembly of tiles to produce a complete image.

Recommended Technologies

- Film scanners
- Planetary scanners
- Digital cameras
- Flatbed scanners

Not Recommended Technologies

- Drum scanners

The tone scale of a photographic negative is non-linear, with a relatively linear mid-section and lower contrast at both the high and low density parts of the film image. If measured and graphed, the values would look somewhat like an “S.” This is commonly known as an “H and D curve”. This curve is different for each film type and each printing media. The pair of negative film and negative photographic print media produces the print image. A photographer would choose between a wide array of options in the creation of a print from the negative. Additional information is available at https://www.nfsa.gov.au/preservation/preservation-glossary/sensitometry.

Given the many combinations of film processes and print media used over time, there is no way to reliably create a digital image from a negative that is a faithful reproduction of how the image may have looked if printed with the original materials and processes of the era. With this fundamental limitation, we are concerned that modern sensibilities of what an image should look like will lead to scans which lose the authenticity of the original in the quest for good looking images.

Photographic negatives may also suffer from degradation, especially color films. It is impossible to visualize the correct color of a color negative, as the orange or red appearance of the film is primarily a proportional dye mask, establishing the appropriate conditions for the color print media it would eventually be printed to. Both this mask and the color dye layers in the film itself fade over time and are influenced by a variety of factors including exposure to heat and improper processing. The current practice of scanning the color negative, inverting the image, and color correcting the positive image does not produce an accurate representation of the original image as it would have looked if printed to photographic paper. Additionally, color negative films produced prior to 1975 (C22 process) do not scan well. Films produced after 1995 were designed to be scanned on the sophisticated digital photographic systems used just prior to the digital camera era.

This presentation provides an overview of photographic film, beginning on slide 16, at https://www.cis.rit.edu/info/HighSchool/pdf/CamPho.pdf

The following methodology is recommended for negative scanning, with the limitations and concerns expressed above: Scan the negative as if it is a transparency, taking care to assure that both highlights and shadows are not clipped. Values as measured on an 8-bit scale should not be less than 5 in the shadows or more than 250 in the highlights. You will need to adjust the exposure settings to take into account the film base density, which can vary widely. Adjust the midtone of the curve if needed to produce an image with a reasonable distribution of tone as viewed on the histogram. This curve adjustment should be made using the scanner controls before scanning the image. Save this image as the archival master.

To create a production master from the above, invert the image to produce a positive image. The resulting image will need to be adjusted to produce a visually pleasing representation. Digitizing negatives is analogous to printing negatives in a darkroom and is very dependent on the photographer's or technician's skill and visual literacy to produce a good image. This work must be done using a calibrated monitor in a proper viewing environment.

It is highly recommended to use color negative inversion and color correction programs that employ "scene balancing" algorithms, which look at the image and adjust for best color using complex calculations. There are several of these programs available in the market today.

When working with scans from negatives, care is needed to avoid clipping image detail and to maintain highlight and shadow detail. The actual brightness range and levels for images from negatives vary with each negative, and images may or may not have a full tonal range.

Significantly improved scans of black and white films can be made using monochrome cameras. Coupled with exposures created using a blue filter over the light source, this technique yields far better results than that obtained using traditional RGB filter (Bayer filter pattern) color systems, which form image data from a block of 1-red, 2-green and 1-blue pixels.

For all film digitization, captures are made at very high magnifications, which exaggerate vibration and other image quality degrading artifacts. It is highly recommended to measure and monitor the quality of captures using standard film targets and analysis software.

Notes

- Negative films vary widely in both density and contrast. Lens flare will reduce the purity of color reproduction and distort the tonality of an image. Very high quality lenses designed for specific reproduction ratios will reduce flare and improve SFR. Working in a dimly lit environment will reduce the effect of ambient light on the image capture.
- Dynamic Range is an informative metric, and not critical for evaluating whether an image is FADGI-compliant. As such the row for this metric is shaded differently than the critical metrics in the table above.
- Appropriate lens selection for film scanning is critical. Lenses designed for general imaging are not appropriate for close focusing film scanning applications. Lenses must be of a flat field design and have the ability to focus all colors at the same plane (apochromatic).
- Sufficient illumination intensity must be available to image at the best performance level for the imaging system. The optimum aperture should be determined through testing, and is generally one to two f stops from maximum aperture. Exposure time should be short enough to eliminate the possibility of vibration affecting resolution and minimize flare from non-image sources.

- Given the lack of calibration targets available for negative films, and appropriate software with which to create calibrations, it is recommended to manually establish scan settings based on highlight, shadow, and midtone measurements of the image being scanned. These settings may need to be changed with every scan, based on the original.
- Imaging with narrow band blue light has been shown to increase the resolution and reduce the effects of Newton’s rings when film is imaged between glass. This is only applicable for monochrome cameras, as a narrow band blue light harms the resolution for a standard Bayer sensor camera.
- The use of antireflective glass is highly recommended. This is not anti-Newton glass commonly used in the past for film scanning.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.12 Photographic Negatives 4” x 5” and Larger

<table>
<tr><th colspan="2">Performance Level:</th><th>1-Star</th><th>2-Star</th><th>3-Star</th><th>4-Star</th></tr>
<tr><td colspan="2">Master File Format</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td><td>TIFF, JPEG 2000</td></tr>
<tr><td colspan="2">Access File Formats</td><td>All</td><td>All</td><td>All</td><td>All</td></tr>
<tr><td colspan="2">Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)[6]</td><td>≥ 485 ppi
(500 ppi – 3%)</td><td>≥ 975 ppi
(1000 ppi – 2.5%)</td><td>≥ 1470 ppi
(1500 ppi – 2%)</td><td>≥ 1980 ppi
(2000 ppi – 1%)</td></tr>
<tr><td colspan="2">Bit Depth</td><td>8</td><td>8</td><td>16</td><td>16</td></tr>
<tr><td colspan="2">Color Space</td><td>Gray Gamma 2.2,
sRGB,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2
sRGB,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td><td>Gray Gamma 2.2,
Adobe RGB (1998),
ProPhoto,
ECIRGB_v2</td></tr>
<tr><td colspan="2">Color Mode</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td><td>Grayscale or Color as appropriate</td></tr>
<tr><th colspan="6">Measurement Parameters</th></tr>
<tr><td colspan="2">*Highlight/Shadow, Tolerance (Units Colorimetric)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td></tr>
<tr><td colspan="2">*Dynamic Range (D max minus D min)</td><td>3.5</td><td>3.8</td><td>3.9</td><td>4.0</td></tr>
<tr><td rowspan="3">◇ Provisional</td><td>Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch</td><td>≤ 5.25</td><td>≤ 4.0</td><td>≤ 2.75</td><td>≤ 1.5</td></tr>
<tr><td>White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch</td><td>≤ 5.25</td><td>≤ 4.0</td><td>≤ 2.75</td><td>≤ 1.5</td></tr>
<tr><td>Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean)</td><td>≤ 8%</td><td>≤ 5%</td><td>≤ 3%</td><td>≤ 1%</td></tr>
</table>

[6] Large format films may have actual resolutions that exceed this specification, but imaging at higher resolutions may exceed practical file sizes.

Color Channel Misregistration (Units Pixels)	≤ 1.2 pixel	≤ 0.8 pixel	≤ 0.5 pixel	≤ 0.33 pixel
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 60%	≥ 70%	≥ 80%	≥ 90%
*SFR Response at Nyquist Frequency (Units Modulation)	< 0.5	< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>30%, <95%]	Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 3%	<+/- 2.5%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)	< 1.15	< 1.1	< 1.05	≤ 1.02

Note: *The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

◊ Unlike the reflection content addressed in most of these guidelines, film content is generally not considered ‘scene referred’ since the film image is one or several generations removed from the original captured scene. The original content by which to judge colorimetric goodness is therefore ambiguous. Nevertheless, some aim response and consistency measure (tolerances) are still required for well-behaved captures. The values cited here have been studied and compared against optical density equivalents up to a density of 2.2 and are considered reasonable values by experts in the field. Until there is evidence to the contrary these values should be adopted provisionally.

Photographic Negatives 4” x 5” and Larger

Recommended Technologies

- Planetary scanners
- Digital cameras
- Flatbed scanners

Not Recommended Technologies

- Drum scanners

The tone scale of a photographic negative is non-linear, with a relatively linear mid-section and lower contrast at both the high and low density parts of the film image. If measured and graphed, the values would look somewhat like an “S.” This is commonly known as an “H and D curve”. This curve is different for each film type and each printing media. The pair of negative film and negative photographic print media produces the print image. A photographer would choose between a wide array of options in the creation of a print from the negative. Additional information is available at https://www.nfsa.gov.au/preservation/preservation-glossary/sensitometry.

Given the many combinations of film processes and print media used over time, there is no way to reliably create a digital image from a negative that is a faithful reproduction of how the image may have looked if printed with the original materials and processes of the era. With this fundamental limitation, we are concerned that modern sensibilities of what an image should look like will lead to scans which lose the authenticity of the original in the quest for good looking images.

Photographic negatives may also suffer from degradation, especially color films. It is impossible to visualize the correct color of a color negative, as the orange or red appearance of the film is primarily a dye mask “filter” setting the appropriate color quality for the color print media it would eventually be printed to. Both this mask and the color dye layers in the film itself fade over time and are influenced by a variety of factors including exposure to heat and improper processing. The current practice of scanning the color negative, inverting the image, and color correcting the positive image does not produce an accurate representation of the original image as it would have looked if printed to photographic paper. Additionally, color negative films produced prior to 1975 (C22 process) do not scan well. Films produced after 1995 were designed to be scanned on the sophisticated digital photographic systems used just prior to the digital camera era.

This presentation provides an overview of photographic film, beginning on slide 16, at

https://www.cis.rit.edu/info/HighSchool/pdf/CamPho.pdf

The following methodology is recommended for negative scanning, with the limitations and concerns expressed above: Scan the negative as if it is a transparency, taking care to assure that both highlights and shadows are not clipped. Values as measured on an 8-bit scale should not be less than 5 in the shadows or more than 250 in the highlights. You will need to adjust the exposure settings to take into account the film base density, which can vary widely. Adjust the midtone of the curve if needed to produce an image with a reasonable distribution of tone as viewed on the histogram. This curve adjustment should be made using the scanner controls before scanning the image. Save this image as the archival master.

To create a production master from the above, invert the image to produce a positive image. The resulting image will need to be adjusted to produce a visually pleasing representation. Digitizing negatives is analogous to printing negatives in a darkroom and is very dependent on the photographer’s or technician’s skill and visual literacy to produce a good image. This work must be done using a calibrated monitor in a proper viewing environment.

It is highly recommended to use color negative inversion and color correction programs that employ “scene balancing” algorithms, which look at the image and adjust for best color using complex calculations. There are several of these programs available in the market today.

When working with scans from negatives, care is needed to avoid clipping image detail and to maintain highlight and shadow detail. The actual brightness range and levels for images from negatives vary with each negative, and images may or may not have a full tonal range.

Significantly improved scans of black and white films can be made using monochrome cameras. Coupled with exposures created using a blue filter over the light source, this technique yields far better results than that obtained using traditional RGB filter (Bayer filter pattern) color systems, which form image data from a block of 1-red, 2-green and 1-blue pixels.

For all film digitization, captures are made at very high magnifications, which exaggerate vibration and other image quality degrading artifacts. It is highly recommended to measure and monitor the quality of captures using standard film targets and analysis software.

Notes

- Negative films vary widely in both density and contrast. Lens flare will reduce the purity of color reproduction and distort the tonality of an image. Very high quality lenses designed for specific reproduction ratios will reduce flare and improve SFR. Working in a dimly lit environment will reduce the effect of ambient light on the image capture.
- Dynamic Range is an informative metric, and not critical for evaluating whether an image is FADGI-compliant. As such the row for this metric is shaded differently than the critical metrics in the table above.
- Appropriate lens selection for film scanning is critical. Lenses designed for general imaging are not appropriate for close focusing film scanning applications. Lenses must be of a flat field design and have the ability to focus all colors at the same plane (apochromatic).
- Sufficient illumination intensity must be available to image at the best performance level for the imaging system. The optimum aperture should be determined through testing, and is generally one to two f stops from maximum aperture. Exposure time should be short enough to eliminate the possibility of vibration affecting resolution and minimize flare from non-image sources.

- Given the lack of calibration targets available for negative films, and appropriate software with which to create calibrations, it is recommended to manually establish scan settings based on highlight, shadow, and midtone measurements of the image being scanned. These settings may need to be changed with every scan, based on the original.
- It may be necessary to capture large format transparencies in multiple tiles and “stitch” the multiple images back together to capture all of the detail in an original transparency. If “stitching” is needed, the completed “stitched” file should be considered the production master, with the stitch elements considered the archival master file.
- Imaging with narrow band blue light has been shown to increase the resolution and reduce the effects of Newton’s rings when film is imaged between glass. This is only applicable for monochrome cameras, as a narrow band blue light harms the resolution for a standard Bayer sensor camera.
- The use of antireflective glass is highly recommended. This is not anti-Newton glass commonly used in the past for film scanning.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.13 Paintings and Other Two-Dimensional Art (Other Than Prints)

Performance Level:	1-Star	2-Star	3-Star	4-Star
Master File Format	JPEG 2000, TIFF	JPEG 2000, TIFF	JPEG 2000, TIFF	JPEG 2000, TIFF
Access File Formats	All	All	All	All
Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)	≥ 292.5 ppi (300 ppi – 2.5%)	≥ 292.5 ppi (300 ppi – 2.5%)	≥ 441 ppi (450 ppi – 2%)	≥ 594 ppi (600 ppi – 1%)
Bit Depth	8	8	16	16
Color Space	sRGB, Adobe RGB (1998), ProPhoto, ECIRGB_v2	sRGB, Adobe RGB (1998), ProPhoto, ECIRGB_v2	Adobe RGB (1998), ProPhoto, ECIRGB_v2	Adobe RGB (1998), ProPhoto, ECIRGB_v2
Color Mode	Grayscale or Color as appropriate	Grayscale or Color as appropriate	Color	Color
Measurement Parameters				
Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch	≤ 6	≤ 4.5	≤ 3	≤ 1.5
Gain Modulation Highlight Patches (average L* between 95 and 85)	Gain between 0.5 and 1.4	Gain between 0.6 and 1.3	Gain between 0.7 and 1.2	Gain between 0.8 and 1.1
Gain Modulation all other patches	Gain between 0.25 and 1.7	Gain between 0.3 and 1.6	Gain between 0.6 and 1.4	Gain between 0.7 and 1.3
White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch	≤ 8	≤ 6	≤ 4	≤ 2
Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean)	≤ 8%	≤ 5%	≤ 3%	≤ 1%

Average Color Accuracy (Units Colorimetric – Mean ΔE_{2000} – average deviation of all patches)	≤ 6.5	≤ 5	≤ 3.5	≤ 2
Color Accuracy 90^{th} Percentile (Units Colorimetric – ΔE_{2000} of all patches)	≤ 13	≤ 10	≤ 7	≤ 4
Color Channel Misregistration (Units Pixels)	≤ 1.2 pixel	≤ 0.8 pixel	≤ 0.5 pixel	≤ 0.33 pixel
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 60%	≥ 70%	≥ 80%	≥ 90%
SFR Response at Nyquist Frequency (Units Modulation)	< 0.5	< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>30%, <95%]	Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]
Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 3%	<+/- 2.5%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)	< 1.15	< 1.1	< 1.05	≤ 1.02
Noise (Upper Limit) (Units Std Dev of L*)	≤ 4	≤ 3	≤ 2	≤ 1
Noise (Lower Limit) (Units Std Dev of L*) – A warning should be raised if the image doesn’t meet this criteria	≥ 0.25	≥ 0.25	≥ 0.25	≥ 0.25

Note: The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

Paintings and Other Two-Dimensional Art (Other Than Prints)

Provisional

Recommended Technologies

- Planetary scanners
- Digital cameras

Not Recommended Technologies

- Drum scanners
- Flatbed scanners

The current best practice often involves color-managed workflows using ICC profiles, but for certain artworks, it may involve extensive experimentation and trial and error to find the most appropriate reproduction process for a given object. These experiments attempt to balance visual inspection on a reference calibrator monitor and data measurements of the original and digital file. Current technology does not permit truly accurate reproduction of many artworks.

Notes

- Artwork reproduction is a unique variant of cultural heritage imaging which tests the limits of imaging science as it exists today. There are many issues that defy solutions:
    - The human eye is able to distinguish a far wider color gamut than is displayable in most ICC profiled environments.
    - The color models used to contain the image data do not match the perception of the human eye.
    - The dynamic range from highlight to shadow can be extreme.
    - Specular highlight reflections obscure detail.
    - Texture may be important to the character of the art.
- Additionally, for certain artworks there can be little practical value to working in a standard ICC profiled environment, given the fact that the profile target colors have little relevance to the colors used by some artists in certain media.
- In most cases a higher resolution (sampling frequency) than 600 ppi of the original object is desirable because the level of detail in artwork exceeds this minimum value. It’s important to analyze the source material and choose a resolution that’s appropriate based on the relationship between the size of the physical object and the level of detail desired. For four-star FADGI compliance, greater than 600 ppi is almost always required to create an appropriate digital reproduction of the original.
- Artwork is rarely truly two dimensional, the third dimensional aspect may be critically important. If the texture of the original is important, image capture may be limited to the single image capture ability of the camera or scanner. Acquiring the image in tiles changes the rendering of the 3D information, making reassembly into one image unreliable. Large single pass slit scanners currently offer the best technology approach for the 3D aspect of artwork imaging.
- Artwork that does not have a dimensional aspect may be captured in multiple tiles and “stitched.” The set of tiles is considered the archival master and the “stitched” version is the production master.
- Research using spectral image capture techniques is currently underway which might advance the state of the art in this field.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.14 X-Ray Film (Radiographs)

Performance Level:	1-Star	2-Star	3-Star	4-Star
Master File Format	TIFF, DICOM, JPEG 2000	TIFF, DICOM, JPEG 2000	TIFF, DICOM, JPEG 2000	TIFF, DICOM, JPEG 2000
Access File Formats	All	All	All	All
Resolution (Sampling Frequency) (Units are Pixels Per Inch/ppi minus Reproduction Scale Accuracy)	≥ 194 ppi (200 ppi – 3%)	≥ 292.5 ppi (300 ppi – 2.5%)	≥ 392 ppi (400 ppi – 2%)	≥ 495 ppi (500 ppi – 1%)
Bit Depth	8	8	16	16
Color Space	Gray Gamma 2.2	Gray Gamma 2.2	Gray Gamma 2.2	Gray Gamma 2.2
Color Mode	Grayscale	Grayscale	Grayscale	Grayscale
Measurement Parameters				
*Highlight/Shadow, Tolerance (Units Colorimetric)	96 +/- 2(L*) 2.7 +/- 1.5 (L*)	96 +/- 2(L*) 2.7 +/- 1.5 (L*)	96 +/- 2(L*) 2.7 +/- 1.5 (L*)	96 +/- 2(L*) 2.7 +/- 1.5 (L*)
*Dynamic Range (D max minus D min)	3.5	3.6	3.9	4.2
◇ Provisional: Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch	≤ 5.25	≤ 4.0	≤ 2.75	≤ 1.5
◇ Provisional: White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch	≤ 5.25	≤ 4.0	≤ 2.75	≤ 1.5
◇ Provisional: Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean)	≤ 8%	≤ 5%	≤ 3%	≤ 1%
SFR10 (Sampling Efficiency) (Measurement is a Ratio %)	≥ 60%	≥ 70%	≥ 80%	≥ 90%
*SFR Response at Nyquist Frequency (Units Modulation)	< 0.5	< 0.4	< 0.3	< 0.2
SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]	Percentage of half sampling frequency: [>30%, <95%]	Percentage of half sampling frequency: [>35%, <85%]	Percentage of half sampling frequency: [>40%, <75%]	Percentage of half sampling frequency: [>45%, <65%]

Reproduction Scale Accuracy (Units % Difference from Header PPI)	<+/- 3%	<+/- 2.5%	<+/- 2%	<+/- 1%
Sharpening (Units Max Modulation)	< 1.15	< 1.1	< 1.05	≤ 1.02
Noise (Upper Limit) (Units Std Dev of L*)	≤ 4	≤ 3	≤ 2	≤ 1
Noise (Lower Limit) (Units Std Dev of L) – A warning should be raised if the image doesn't meet this criteria	≥ 0.25	≥ 0.25	≥ 0.25	≥ 0.25

Note: *The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

◊ Unlike the reflection content addressed in most of these guidelines, film content is generally not considered 'scene referred' since the film image is one or several generations removed from the original captured scene. The original content by which to judge colorimetric goodness is therefore ambiguous. Nevertheless, some aim response and consistency measure (tolerances) are still required for well-behaved captures. The values cited here have been studied and compared against optical density equivalents up to a density of 2.2 and are considered reasonable values by experts in the field. Until there is evidence to the contrary these values should be adopted provisionally.

X-Ray Film (Radiographs)

Recommended Technologies

- Specialized cameras that are capable of capturing a high dynamic range (can achieve a range of 5.0)

Not recommended Technologies

- Color Digital cameras
- Drum scanners

Few scanners are capable of imaging radiographs properly due to their very wide density range and large size. There are specialized film scanners built for this application. These are generally the most appropriate. For other capture systems, blending multiple captures commonly referred to as high dynamic range (HDR) imaging, may be beneficial in capturing the wide tonal range present in the films. An overview of HDR imaging can be found at https://www.adobe.com/creativecloud/photography/hub/guides/what-is-hdr-photography

Notes

- Radiographs have a very high d-max, often exceeding 4.0, with detail over the entire range from about .10. Few scanners can accurately image this range in one pass, and few can save in the DICOM format that is standard for this image type.

- Industry standard specifications for these film scanners is 500 ppi. FADGI conforms to this convention.
- The DICOM format originates in the medical imaging world, and has been adopted in cultural heritage. Either DICOM or TIFF is appropriate as a master format. DICOM is preferred, being essentially a raw format which allows the user to adjust the rendering of the image to examine an area of interest by changing the rendering parameters. More about DICOM can be found at https://dicom.nema.org/medical/dicom/current/output/chtml/part01/chapter_1.html#sect_1.1
- Dynamic Range is an informative metric, and not critical for evaluating whether an image is FADGI-compliant. As such the row for this metric is shaded differently than the critical metrics in the table above.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

3.15 Printed Matter, Manuscripts, and Other Documents on Microfilm

<table>
<tr><th colspan="2">Performance Level:</th><th>1-Star</th><th>2-Star</th><th>3-Star</th><th>4-Star</th></tr>
<tr><td colspan="2">Master File Format</td><td>TIFF, JPEG2000</td><td>TIFF, JPEG2000</td><td>TIFF, JPEG2000</td><td>TIFF, JPEG2000</td></tr>
<tr><td colspan="2">Access File Formats</td><td>All</td><td>All</td><td>All</td><td>All</td></tr>
<tr><td colspan="2">Resolution (With Respect to the Microfilm Frame Size) (Sampling Frequency) (Units are Pixels Per Inch/ppi</td><td>≥ 3000 ppi</td><td>≥ 3500 ppi</td><td>≥ 4000 ppi</td><td>≥ 4500 ppi</td></tr>
<tr><td colspan="2">Bit Depth</td><td>8</td><td>8</td><td>8</td><td>8</td></tr>
<tr><td colspan="2">Color Space</td><td>Gray Gamma 2.2</td><td>Gray Gamma 2.2</td><td>Gray Gamma 2.2</td><td>Gray Gamma 2.2</td></tr>
<tr><td colspan="2">Color Mode</td><td>Grayscale</td><td>Grayscale</td><td>Grayscale</td><td>Grayscale</td></tr>
<tr><th colspan="6">Measurement Parameters</th></tr>
<tr><td colspan="2">*Highlight/Shadow, Tolerance (Units Colorimetric)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td><td>96 +/- 2(L*)
2.7 +/- 1.5 (L*)</td></tr>
<tr><td colspan="2">*Dynamic Range (D max minus D min)</td><td>3.5</td><td>3.8</td><td>3.9</td><td>4.2</td></tr>
<tr><td rowspan="3">◇ Provisional</td><td>Tone Response (OECF) L* (Units Colorimetric ΔL_{2000}*) for any given gray patch</td><td>≤ 5.25</td><td>≤ 4.0</td><td>≤ 2.75</td><td>≤ 1.5</td></tr>
<tr><td>White Balance (Units Colorimetric ΔE(a*b*)) for any given gray patch</td><td>≤ 5.25</td><td>≤ 4.0</td><td>≤ 2.75</td><td>≤ 1.5</td></tr>
<tr><td>Lightness Uniformity (Units Colorimetric – Standard Deviation Divided by Mean)</td><td>≤ 8%</td><td>≤ 5%</td><td>≤ 3%</td><td>≤ 1%</td></tr>
<tr><td colspan="2">SFR10 (Sampling Efficiency) (Measurement is a Ratio %)</td><td>≥ 60%</td><td>≥ 70%</td><td>≥ 80%</td><td>≥ 90%</td></tr>
<tr><td colspan="2">*SFR Response at Nyquist Frequency (Units Modulation)</td><td>< 0.5</td><td>< 0.4</td><td>< 0.3</td><td>< 0.2</td></tr>
<tr><td colspan="2">SFR50 (50% SFR) (Units Percentage of Half Sampling Frequency) [Lower, Upper]</td><td>Percentage of half sampling frequency: [>30%, <95%]</td><td>Percentage of half sampling frequency: [>35%, <85%]</td><td>Percentage of half sampling frequency: [>40%, <75%]</td><td>Percentage of half sampling frequency: [>45%, <65%]</td></tr>
</table>

Note: *The white rows with light gray text in the table above are informative only, and are not required parameters for each FADGI star level. The Digital Count metrics have been removed from this version of the *Guidelines*.

◊ Unlike the reflection content addressed in most of these guidelines, film content is generally not considered ‘scene referred’ since the film image is one or several generations removed from the original captured scene. The original content by which to judge colorimetric goodness is therefore ambiguous. Nevertheless, some aim response and consistency measure (tolerances) are still required for well-behaved captures. The values cited here have been studied and compared against optical density equivalents up to a density of 2.2 and are considered reasonable values by experts in the field. Until there is evidence to the contrary these values should be adopted provisionally.

Printed Matter, Manuscripts, and Other Documents on Microfilm

These guidelines apply to monochrome 16mm, 35mm, and microfiche. Color microfilm and microfiche are out of the scope of these recommendations.

When scanning microfilm, often the desire is to produce images with legible text. Due to photographic limitations of microfilm and the variable quality of older microfilm, it may not be possible to produce what would normally be considered reproduction quality image files. The choice of scanning approach may vary from the recommendations cited here for textual records, and may be more focused on creating digital images with reasonable legibility.

The convention when creating microfilm from original materials was to note the “reduction” ratio of the image capture on film to the original size of the source. In many if not most cases, this information was not captured on the film itself at the start of imaging, and may have been lost over time.

If the reduction ratio is known that information should be captured in the metadata of the digital image. This will inform the size of the original document when combined with the known imaging resolution.

Digitization of microfilm is done to a known ppi resolution of image capture, unrelated to the size of the original. This optimizes the quality of the digital file with the known capabilities of microfilm scanners and the known inherent resolution of the microfilm itself.

Notes

- Digital reproductions should be made from a preservation copy of microfilm, if available.
- Scan the full content of the microfilm frame.
- Capture images of standard targets at the start and end of each session.
- The reduction scale of the microfilm may be unknown, given that there is no way to confirm the original imaging parameters. These guidelines refer to ppi resolution of the digital capture, not the original documents.
- If the project requires “crop to page”, the cropped versions of the digital files are considered production masters.
- Imaging with narrow band blue light has been shown to increase the resolution and reduce the effects of Newton’s rings when film is imaged between glass. This is only applicable for monochrome cameras, as a narrow band blue light harms the resolution for a standard Bayer sensor camera.
- The use of antireflective glass is highly recommended. This is not anti-Newton glass commonly used in the past for film scanning.
- In any situation where there is potential harm to the original, stop immediately and seek assistance.

Chapter 4: Digitization Equipment

It is beyond the scope of this document to provide recommendations on specific digitization equipment, and such advice would quickly become obsolete if we did. However, it is within the scope to discuss classes of digitization equipment and their application to cultural heritage digitization. It is also worth noting that while digitization can be done on a budget, it is important to look at total cost factors rather than merely the cost of a single piece of equipment. Total cost factors may include employees/salary, space, equipment, time, and other resources required for a project.

4.1 Camera

Digital cameras have become first line digitization tools in the cultural heritage community in the past few years. It is common to have digital cameras with 100 to 150MP sensors coupled with very high quality lenses that together provide a fast and high quality digitization system. However, digital cameras have limitations.

The principal limitation is the imaging sensor. The sensors used in digital cameras cannot "see" color. To solve this problem micro color filters are coated on each pixel site of the sensors in what is known as the Bayer (or similar) filter pattern. Inevitably this leads to reduced resolution and imperfect color. Very sophisticated algorithms translate the information and interpolate full color data for each of the four pixels. In essence, the true resolution is less than the stated resolution, and the color is interpolated from the data from four pixels.

However, the results are compelling and the cultural heritage community has embraced professional digital cameras. Given the complexity of these imaging systems, it is essential to test the entire imaging system for performance.

A few digital cameras use monochrome sensors, without the Bayer filter. These specialty cameras may be appropriate when imaging monochrome materials, and may be incorporated into digitization systems that use multi-exposure processes to achieve color, hyper-spectral and multi-spectral images. Recent testing using very high-quality monochrome sensors have produced truly impressive results, especially when imaged using narrow band blue light.

4.2 Lens

High quality optics are critically important in cultural heritage imaging. All lenses are designed and optimized for specific applications, and there may be significant variability in the performance of two identical lenses. Digital image conformance evaluation testing will validate performance specifications of the lens as integrated in the total imaging system. Generally, apochromatic and macro lenses outperform other lenses for cultural heritage close focusing applications, and lenses designed specifically for digital flat field imaging are best. It is important to assure that the image circle of the lens is appropriate for the imaging sensor used and that the lens is designed to be used at the working magnifications needed.

As digital sensors become available in ever higher pixel counts, the quality of the lens becomes a critical factor in actual system resolution. It has reached the point where the resolution of digital cameras and scanners may be limited by the performance of the lens, and in some cases a theoretically perfect lens cannot match the resolution capability of available digital sensors. More pixels on the sensor may not relate to increased resolution in the digital file.

4.3 Scanner

Digital scanners use several different technologies to capture images. The oldest of these is the photomultiplier tube (PMT) used primarily in drum scanners. To this day, drum scanners provide the highest image quality of all imaging devices, but due to the risk of damage to originals and inherently slow speed, they are inappropriate for most cultural heritage digitization.

The predominant technology used in scanners today is the linear, or tri-linear array. This is a one pixel line of sensors the length of the device, sensing only one color through a solid filter, or gray without a color filter. Linear scanners can image both reflective and transmissive materials, depending on the design of the scanner. These scanners rely on very precise movement of either the original or sensor in relation to the original, capturing data one line at a time as the system "scans" across the object. In a tri-color configuration, there is a distance gap between the three rows of sensors, which is compensated for as the image is constructed in software.

4.3.1 Planetary Scanner

This class of scanner uses one of two methods to capture an image. Either the sensor moves in the camera head capturing the image one line at a time or the sensor remains stationary and the object moves under the camera, again capturing the image one line at a time. Beyond this difference, there is great similarity to a digital camera on a copy stand. Planetary scanners have the advantage of being able to capture images in very high resolution, due to the very long high-resolution linear sensors available, and the unlimited ability to add rows of scans in one dimension if the system moves the original under the camera. However, they take time to capture an image and are only efficient for original materials that can be held flat during the long exposure cycle.

4.3.2 Flatbed Scanner

The flatbed scanner has found a home in almost every digitization facility in the world. They can be fast, very high "resolution," easy to use, and versatile, scanning everything from film to documents. Few of this breed, though, have a place in a cultural heritage digitization project. Perhaps the best policy to adopt in considering flatbed scanners is you get what you pay for. Beware of fantastic claims of resolution or dynamic range. Rely on digital image conformance evaluation testing to verify the results. For almost every application where a flatbed scanner might be used, there is a better solution using other tools. However, FADGI recognizes that flatbed scanners have their place and may be appropriate for some applications.

4.3.3 Film Scanner

Film scanners are perhaps the least understood class of digitization equipment. Under the hood they are really either a planetary scanner or digital camera, with the exception of true drum scanners, which are single point acquisition devices. What makes film scanners unique is the software designed to interpret the film image and convert the digital data into an image file that resembles the final original image, which is a generation away from the film itself in the case of either a color or black and white negative. This is an especially difficult task for negatives since they lack a visual scene reference, and rely on an operator's interpretation of the digitized negative.

4.3.4 Drum Scanner

Drum scanners function by securing either reflection or transmission originals to the surface of a "drum," generally with tape. The drum then spins at high speed and individual pixels are acquired through a focused lens one at a time as the drum spins. Very high quality scans can be produced from high quality drum scanners, but there is risk to the original as it spins attached to the drum. These systems are also quite slow. Given the risk to the original and the method of attachment, these scanners have very limited application in cultural heritage imaging.

4.4 Selection of Digitization Equipment

Proper selection of digitization equipment is an essential element of a successful digitization program. Factors to consider are

- Type of materials to be digitized
- Size of the originals
- Quantity of each type of original
- Condition of the materials and how they can be handled during scanning
- Staff digitization experience and quantity
- Budget
- Physical space available

- Duration of the project
- Intended end use of the digitized images[7]

Chapter 5: Imaging Workflow

5.1 Overview

Digitization workflow planning follows the steps outlined below. It is a balancing act – each part needs to be designed to work with the others, and function at the same capacity. If designed and implemented properly, digitization can be a smooth and efficient process. If any one element of the process is not designed and/or implemented correctly, the whole system can become inefficient and wasteful.

Follow these steps in designing a digitization workflow appropriate for your project.

5.1.1 Define the Requirement

Planning begins with an evaluation of the requirement. These questions need to be answered:

- What is the scope of the requirement?
- What is the timeframe required for completion?
- What types of materials are involved?
- What is the expected result?
- What is the goal of the project? Is it to make an “accurate” image? A “nice” image?

5.1.2 Assess Organizational Capabilities

Once the project is defined, review the capabilities of the organization to accomplish the goal defined above. Questions to answer:

- What staff resources are available?
- What are the digitization skills of the available staff?
- What physical space is available to devote to the effort?
- What digitization equipment is available?
- What new digitization equipment is needed?
- What level of funding/resources is available?

5.1.3 Insource vs. Outsource

If the capabilities of the organization are determined to not be equal to the requirement, the issue needs to be addressed, or the decision to outsource the project needs to be made.

The answer to this question may determine the success or failure of the program. A project with inadequate resources may produce results with little or no long-term value, and could even result in damage to or loss of the collections. A well-planned and executed effort will save time, effort, and resources.

Resist the temptation to dive into a digitization project without proper resources. If the organization does not have the resources, it may be best to outsource the project. Also, avoid the trap of assuming doing the work in-house will cost less. Insourcing may cost more than outsourcing.

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[7] The intended end use for a digital image (presentation, archives, reference, etc.) should be a factor when considering what equipment to use, as different end uses demand different levels of image quality. For example, for access only images, the expectation demands for image "goodness" will not be as high as a collection being digitized to FADGI 4* criteria.

5.1.4 Project Management

Critically important to the success of any project is project management. Set target production goals and establish a system to measure progress. Establish a quality monitoring system based on the digital image conformance evaluation system to verify the results and inform if adjustments are needed. Keep records of both quality and quantity.

5.1.5 Workflow Plan

Once the project is defined and decisions concerning project management and insourcing vs. outsourcing have been made, a workflow plan needs to be developed.

The workflow plan takes into account the flow from ingest through archive, which includes the following steps:

- Selection of materials
- Condition evaluation
- Cataloging
- Metadata creation
- Production scheduling
- Digitization prep
- Digitization
- Post processing
- Quality review
- Archiving
- Publishing

5.2 Large Scale Project Workflow

Selection of Materials

Project workflow plans are unique to each situation, but all follow the same logic. Starting with the selection of the materials. Decisions need to be made about the types of materials that will be digitized, and in what sequence. Grouping like materials together can create efficiencies in acquisition process, but may create organizational challenges. Switching back and forth among digitization setups is time consuming and disruptive. Production planning is necessary to balance the competing elements to achieve the most efficient production.

Collection Survey

Potential collections being considered for digitization should be surveyed and processed. This is a necessary step for discovery, condition, planning for digitization, and future needs, such as storage and risk analysis/disaster planning. This may also include a 10% sample of the collection reviewed by conservation. Please see this American Natural History Museum page for more information about collection surveys at https://www.amnh.org/research/science-conservation/methodologies/surveys

Condition Evaluation

All materials to be digitized should be evaluated for their condition, and appropriate steps taken if problems are discovered. Materials may have mold issues, which present health risks, or may suffer any number of other issues that should be evaluated before digitization. An initial evaluation may include only a percentage of the collection, but each item should be examined individually prior to imaging.

Metadata

Metadata should generally be acquired before digitization begins. Technical metadata should be generated during digitization. Please see the next section for more information on metadata.

Production Scheduling

Selection, condition evaluation, and metadata creation should be designed to fit efficiently with later processing actions. The process should be designed to have a buffer of project work ready for digitization to permit flexibility in scheduling. If the project involves multiple scanners and material types, buffers for each imaging task should be maintained. Production scheduling is the essence of an efficient project.

Digitization Prep

Materials are assembled in the workspace and made ready to digitize. Information about file naming, shoot order, project specifications, etc., should be clearly organized. Art conservation treatment should be completed, and special handling needs addressed in advance.

Digitization

The actual digitization process will vary dramatically based on the type of materials being digitized and the scale of the effort. FADGI does not provide recommendations on the specific design of digitization projects. Best practice dictates imaging an appropriate target at the beginning of a session. The target should be checked and verified as passing prior to beginning imaging. If the target does not pass, this is the opportunity to correct equipment and settings prior to beginning imaging. A supervisor should be consulted if the target continuously fails. If the session is disrupted by a break, etc., the target should be re-imaged and checked and verified before resuming the session.

Post Processing

This process is highly specific to the project goals, but in general involves adjustment of the files to a common standard image specification and project specific requirements. It may or may not involve the generation of derivative files and the creation of file folder structures and metadata.

Quality Review

Separate from the post process step is quality review. This process may involve automated inspection for conformance to technical specifications, followed by physical inspection, where an inspector reviews a representative sample of the project to verify conformance to the project specifications. The size of the sample is determined in the project planning stage. Automated tools such as JHOVE or Jpylyzer can assist in verification of the files.

Archiving

Once the project, or segment of the project if appropriate, has passed quality review, it is passed on to be archived. Additional testing for file integrity may be done at this stage. Refer to the section on storage options for additional information.

Publishing

Master files are not suitable for presentation, except in unusual circumstances. For publishing or presentation, derivative files are created in an appropriate format for the application. These can be created as a structured process in post processing, or dynamically as needed. Care must be taken to assure that color transformations are done correctly as appropriate for each application.

The following section outlines – in broad strokes – the workflows that have been utilized effectively in several Federal agencies. They are presented for reference and as a guide to designing workflows.

Example Workflow #1

The following is an example of a project that has a distinct goal and end point. There is a collection of paper materials that needs to be digitized in its entirety.

- Selection of material

- All objects are of various sizes and materials but the overall project is so vast that the determination is to scan everything in the same manner on the same device.
    - All objects are scanned with the same resolution
- Materials are in the same location and stored in the same manner. Therefore, organization is uncomplicated as long as it is tracked through the use of databases amongst staff.
- Some material throughout the collection has already been scanned. Items that have been digitized previously are reviewed, and it is determined by staff whether or not to rescan based on the quality of digitized file.

- Condition evaluation
    - Objects are pulled and reviewed by conservation staff to determine whether or not digitization is safe for each object.
    - Some objects need to be rehoused or unfolded in order for digitization to occur safely.
    - Special handling may be required for oversized objects (i.e., need at least two people to handle the item) or for extremely fragile items like onion skin maps.
    - Many objects are housed in Mylar and some of them are too fragile to remove from the housing. This determines how the items need to be scanned in order to avoid unnecessary reflections and distortions.
- Cataloging
    - The number of materials in the collection is unknown at the beginning of a project. The digitization process will determine the actual number of items, and limit the amount of handling required.
    - Many objects have not been cataloged to date.
        - Recording as much information about the object into the database for future cataloging is critical.
- Metadata creation
    - Objects that are ready for digitization are reviewed and named with a specific digital filename. The filename is recorded into a database with the corresponding call number, unique data about the item, and information about the digitization including: what date it was scanned, who scanned it, and what equipment scanned it.
    - For objects that have been previously cataloged, the LCCN is also recorded.
    - Filenames contain both letters and numbers and will signify both the abbreviated collection name and a unique number. Copy number and/or bibliography numbers have also been appropriated within the digital filename.
    - At the time of the scan, a signifying character is appended to each filename indicating that the scan is an “unprocessed” scan.
    - Because many items are oversized and cannot be scanned in one image, a grid pattern is determined and carried out with letter or character identifiers appended to the unprocessed filename.
    - Technical metadata is created and saved from the time of the scan.
- Production scheduling
    - Staff resources are limited and the digitization process is largely handled by one person.
    - After a group of objects are pulled, one person names it, digitizes it, and performs post-processing as needed.
    - Most items are fragile and although an extra hand would be helpful during the handling of the item, the process is mainly individual.
    - Other digitization efforts are recorded into the same databases, and having one person responsible for the majority of the digitization of the specific object limits confusion and mistakes.
- Digitization prep
    - Filenames are created and recorded into both the database and onto the storage housing of the object.
    - Because items are scanned at the same resolution, grouping of objects may occur due to type of material.
        - Example – there are multiple onion skin objects that need a backing while scanned.
        - Example – different collections are being scanned in the same session and are therefore grouped according to filename.

- Digitization
  - Determine the appropriate spatial resolution for the project.
  - Determine the appropriate ICC color space (sRGB, Adobe RGB 1998, etc.).
  - Small targets are placed within each unprocessed scan to monitor and track the color accuracy of each image. This target will be cropped out of the final image in order to ensure no confusion for the end-user. These targets measure the digitizing environment of the actual material and not the equipment.
  - Once a day, a target used to measure the equipment is also scanned. This is used by digitization staff to track and monitor the scanning equipment's performance through time. Results from testing are used to create custom color profiles, to fine-tune sharpening and resolution settings, and to monitor any variances in quality.
  - Items are generally scanned in the numerical order that they are named to streamline the process.
  - Many of the items are housed in Mylar and need to be positioned accordingly on the scanner bed to avoid glare and unwanted reflections.
  - Processes of digitization are grouped together (i.e., all naming and inputting into database at once, and then all scanning) for efficiency.
  - Once object has been scanned, the housing folder will be labeled with a "scanned" label to alert all future staff and patrons of an already digitized object.
  - Post-processing includes de-skewing and cropping as well as minimal tonal adjustment, done within the lightness channel in L*a*b* mode.
  - Minimal sharpening is done within the scanner software at the time of scanning and not applied in post-processing.
  - The ability to read information accurately and in the way that the original is represented is the main concern here.
  - Since many objects are so large and cannot be scanned in one image, multi-part scans also need to be combined into a presentation file.
    - Merging files is unacceptable because of the inevitable loss of information.
    - Files are generally "placed" next to their counterparts allowing blank space to occur between each part and therefore alerting the user that the files have been combined.
- Quality review
  - All images are reviewed as thumbnails in a digital asset management (DAM) platform
  - Selected images are reviewed 1:1 in an appropriate image viewer and metadata verified.
  - Review is done on color calibrated monitors.
- Archiving
  - Archiving digitized material is done both on a personal staff-member's level as well as on the library level.
  - Much of the scanning equipment does not have access to the local intranet and shared drives
    - Images will be scanned to a staff-member's portable hard drive.
    - Images are also copied to the staff-member's computer.
    - As both an extra back-up copy and also an access copy, the images are copied to the library's processing space.
  - Because little processing has been done to the images, the processed version of the scanned image is an archival copy.
    - The un-processed version is usually saved until the processed image is reviewed and published.
- Publishing
  - Different versions and file types of the same image are created in order to be accessible to all patrons and users.
    - These derivatives include thumbnail JPEG, TIFF, and GIF.
    - Only the processed copy (with minor adjustments and combined when necessary) is published.

Example Workflow #2

The following is an example of digitizing "on-demand." When there is a group of objects that needs to be digitized (either for an internal or external request), scanning requirements and goals are specially created. There is no distinct end point and the project always varies in terms of materials and goals.

- Selection of material
  - Objects range in size and material and different resolutions, lighting set-ups, and/or equipment are needed to capture both detail and color accurately.
    - Example – engravings need to be digitized at higher resolutions in order to avoid moiré.
    - Example – negatives and other transmissive materials will need backlighting either with a light box on a copy stand or a particular setting on a flatbed scanner.
    - Example – stereographs cannot be scanned on a flatbed scanner because of the curve and must be scanned on a copy stand set-up. They may also require special lighting set-ups to avoid distracting shadows and reflections.
  - Similar materials are sorted into groups to be scanned at the same time with the appropriate device.
  - Objects are reviewed individually to determine appropriate resolution and equipment set-up.
- Condition evaluation
  - Objects have been requested for digitizing and have therefore been reviewed by reference or curatorial staff beforehand.
  - A "shooting list" of needed materials is created, alerting the digitization specialist of specific details regarding each object (i.e., resolution, cropping).
- Cataloging
  - Most objects are cataloged ahead of time.
- Metadata creation
  - The "shooting list" is referred to again for specific digital filenames (digital ID's).
  - All digital ID's are unique to the division and may contain specific information about the type of file, the collection that the file is in, or even the bit depth of the file.
  - Technical metadata is created and saved from the time of the scan.
- Production scheduling
  - Some materials warrant a helper to assist with handling items.
    - This allows the scanner to input filenames and focus on image quality.
  - Many other materials are scanned and post-processed by the same individual.
  - Other processes such as file naming, quality review, derivative making and publishing can be done for multiple files and groups of objects by one individual.
- Digitization prep
  - Items from shooting list are pulled and grouped into "like objects."
    - Example – all prints that need to be scanned at 300ppi are grouped together and all engravings that need to be scanned at 600ppi are grouped together.
    - Example – photographic prints that are highly reflective and need special lighting set-ups to avoid glare are grouped together.
- Digitization
  - Once every scan session (or when a resolution is changed), a target used to measure the equipment is scanned. This is used by digitization staff to track and monitor the scanning equipment's performance. Results from testing are used to create custom color profiles and to fine-tune sharpening and resolution settings.
  - If digitization allows for downtime, operator can complete other tasks simultaneously, such as metadata input or post processing.
  - Post-processing includes de-skewing and cropping as well as minimal tonal adjustment.
  - Color accuracy and likeness to the original, in its current state, is the main concern in scanning here.
  - Minimal sharpening is done within the scanner software at the time of scanning and not applied in post-processing.
  - If a material "helper" is available, the scanner can focus on operating the software and appropriately changing quality settings.
  - Some objects are too large to be captured in one scan
    - These files can be merged with a process like "Photomerge" in Photoshop.

- Quality review
  - Materials that have been scanned in various sessions are reviewed by other staff members on color calibrated monitors.
    - Aspects such as excess dust and hair, skew, improper cropping and poor tonal quality are all reviewed.
    - The goal is only to show the material in its true form and not to improve upon the material. (i.e. removing permanent dust and hair)
- Archiving
  - Archiving digitized material is done both on a personal staff-member's level as well as on the library level.
  - Much of the scanning equipment does not have access to the local intranet and shared drives
    - Images will be scanned to a staff-member's portable hard drive.
    - Images are also copied to the staff-member's computer.
    - As both an extra back-up copy and also an access copy, the images are copied to the Library's processing space.
  - Because little processing has been done to the images, the processed version of the scanned image is an archival copy.
    - The un-processed version is usually saved until the processed image is reviewed and published.
- Publishing
  - Different versions and file types of the same image are created in order to be accessible to all patrons and users.
    - These derivatives include thumbnail JPEG, TIFF, and GIF.
    - Only the processed copy (with minor adjustments) is published.
    - In some cases, merged files are presented as the final copy along with its various uncombined parts, making file sizes more manageable when needed.

5.3 Small Scale Project Workflow

Small scale projects follow the same steps defined above, but are adjusted to fit the realities of a smaller project. Generally, that means there may be only one person tasked with performing all of the steps, on one computer and with limited resources. Production efficiency that comes with the use of expensive digitization equipment is traded for the affordability of lesser, or slower equipment, and the realization that some digitization tasks cannot be done. In minimalist form, this might be a flatbed scanner and a single operator working with free software on a single computer. This entire system can be assembled for a few hundred dollars, even less with creative acquisition strategies.

Stepping up to a digital camera moves the cost of a workable system to a few thousand dollars, but opens up many more possibilities for digitization of various materials, including dimensional objects.

Small scale projects using basic tools should easily achieve FADGI level 2, and may achieve higher FADGI levels. In the case of specialized materials a solid argument can be given to aim for FADGI level 4. Scanners and cameras vary dramatically in their capabilities. Careful selection and implementation, using digital image conformance evaluation testing as a guide, can reward you with a high quality capability at very low cost.

5.3.1 Sample Image Processing Workflow

The following provides a general approach to image processing for a small scale project that should help minimize potential image quality defects due to various digital image processing limitations and errors. Depending on the scanner/digital camera, scan/capture software, scanner/digital camera calibration, and image processing software used for post-scan adjustment and/or correction, not all steps may be required and the sequence may need to be modified.

Fewer steps may be used in a high-volume scanning environment to enhance productivity, although this may result in less accurate tone and color reproduction. Scan a target, adjust controls based on the scan of the target, and then use the same settings for all scans - this approach should work reasonably well for reflection scanning, but will be much harder to do when scanning copy negatives, copy transparencies, original negatives, and original slides/transparencies.

Consider working in high-bit mode (48-bit RGB or 16-bit grayscale) for as much of the workflow as possible if the scanner/digital camera and software is high-bit capable, and the computer used has enough memory and speed to work with the larger files. Conversion to 24-bit RGB or 8-bit grayscale should be done at the end of the sequence.

Scanning

- Adjust size, scaling, and spatial resolution.
- Color correction and tone adjustment
- Follow established aimpoint guidance – remember there are always exceptions and you may need to deviate from the recommended aimpoints, or to adjust image based on a visual assessment and operator judgment.
- Recommended – use precision controls in conjunction with color management to achieve the most accurate capture in terms of tone and color reproduction.
- Alternative – if only global controls are available, adjust overall color balance and compress tonal scale to minimize clipping.
    - No sharpening or minimal sharpening (unsharp mask, applied to luminosity preferred).
    - Color profile conversion (might not be possible at this point, depends on scanner and software).
- Convert from scanner space to Adobe RGB (1998) for color images or Gray Gamma 2.2 for grayscale images.
- Generally, for color image profile conversion, use relative colorimetric rendering intent for near-neutral images (like most text documents), and perceptual rendering intent for photographic and other wide-gamut, high-saturation images.

Check the accuracy of the scan. You may need to adjust scanner calibration and control settings through trial-and-error testing to achieve best results.

Post-Scan Adjustment/Correction

- Color profile assignment or conversion (if not done during scanning)
- Either assign the desired color space or convert the image from scanner space. Use the approach that provides best color and tone accuracy.
    - Adobe RGB (1998) for color images or Gray Gamma 2.2 for grayscale images.
- Generally for color image profile conversion, use relative colorimetric rendering intent for near-neutral images (like most text documents), and perceptual rendering intent for photographic and other wide-gamut, high-saturation images.
- Color correction
    - Follow aimpoint guidance - remember that there are always exceptions and you may need to deviate from the recommended aimpoints, or adjust the image based on a visual assessment and operator judgment.
    - Use precision controls (levels recommended, curves alternative) to place and neutralize the black-point, place and neutralize the white-point, and to neutralize the mid-point. When color correcting photographic images, levels and curves may both be used.
    - Alternative – if only global controls are available, adjust the overall color balance.
- Tone adjustment
    - Use precision controls (levels recommended, curves alternative) to adjust all three aimpoints in an iterative process. There are always exceptions and you may need to deviate from the recommended aimpoints, or adjust the image based on a visual assessment and operator judgment.
    - Alternative – if only global controls are available, adjust contrast and brightness.

- De-skew and/or crop
- Check image dimensions and resize
- Sharpen
    - For color files, apply unsharp mask to luminosity information only. Many image editing applications have the ability to apply unsharp mask to luminosity in high-bit mode. Sharpening should be done prior to the final conversion to 8-bits per channel.
- Save file

The actual image processing workflow for small scale projects will depend on the originals being digitized, the equipment and software being used, the desired image parameters, and the desired productivity.

Chapter 6: Adjusting Image Files

There is a common misconception that image files saved directly from a scanner or a digital camera are pristine or unmolested in terms of image processing. Even “raw” files from scanners or digital cameras have been adjusted by the camera. All digital image files have a range of image processing applied during scanning, and prior to saving, in order to produce digital images with good image quality. But it should be kept in mind that the concept of less being more applies to post-processing.

Because of that misconception, many people argue that one should not perform any post-scan or post-capture adjustments on image files because the image quality might be degraded. We disagree. The only time we would recommend saving unadjusted files is if they meet the exact tone and color reproduction, sharpness, and other image quality parameters that are required. Otherwise, we recommend doing minor post-scan adjustment to optimize image quality and bring all images to a common rendition. Adjusting master files to a common rendition provides significant benefits in terms of being able to batch process and treat all images in the same manner. Well-designed and calibrated scanners and digital cameras can produce image files that require little or no adjustment. However, based on our practical experience, there are very few scanners/cameras that are this well designed and calibrated.

Cultural Heritage digitization aims to reproduce the original as faithfully as possible across multiple brands and types of capture devices. The only way to achieve this goal is to employ system-level color calibration and adjustment, which nulls the differences between capture devices and different calibration approaches by different manufacturers. This is an emerging concept which has shown exciting results.

Also, some people suggest that it is best to save raw image files, because no “bad” image processing has been applied. This assumes that one can do a better job adjusting for the deficiencies of a scanner or digital camera than the manufacturer, and that one has a lot of time to adjust each image. Raw image files will not look good on screen, nor will they match the appearance of originals. Raw image files cannot be used easily; this is true for inaccurate unadjusted files as well. Every image, or batch of images, will have to be evaluated and adjusted individually. This level of effort will be significant, making both raw files and inaccurate unadjusted files inappropriate for master image files. Additionally, sustainability of format should be considered. Many formats have become obsolete over time, thus making image files inaccessible. Consider carefully the longevity of file type when deciding what file format should be used.

We believe that the benefits of adjusting images to produce the most accurate visual representation of the original outweigh the insignificant data loss (when processed appropriately), and this avoids leaving images in a raw unedited state. If an unadjusted/raw scan is saved, future image processing can be hindered by unavailability of the original for comparison. If more than one version is saved (unadjusted/raw and adjusted), storage costs may be prohibitive for some organizations, and additional metadata elements would be needed. In the future, unadjusted or raw images will need to be processed to be used and to achieve an accurate representation of the originals, and this will be difficult to do.

6.1 Overview

We recommend using the scanner/camera controls to produce the most accurate digital images possible for a specific scanner or digital camera. Minor post-scan/post-capture adjustments are acceptable using an appropriate image processing workflow that will not significantly degrade image quality.

We feel that the following goals and tools are listed in priority order of importance.

1. Accurate imaging – use scanner controls and reference targets to create grayscale and color images that are:
    - Reasonably accurate in terms of tone and color reproduction.
    - Consistent in terms of tone and color reproduction, both image-to-image consistency and batch-to-batch consistency.
    - Reasonably matched to an appropriate use-neutral common rendering for all images.
2. Color management – as a supplement to accurate imaging, use color management to compensate for differences between devices and color spaces:
    - To achieve best accuracy in terms of tone, color, and saturation, use custom profiles for capture devices, and convert images to a common wide-gamut color space to be used as the working space for final image adjustment. Readily available “generic” ICC profiles cannot achieve the level of accuracy needed for Cultural Heritage applications.
    - Color transformation can be performed at time of digitization or as a post scan/digitization adjustment.
3. Post scan/digitization adjustment - use appropriate image processing tools to:
    - Achieve final color balance and eliminate color biases (color images).
    - Achieve desired tone distribution (grayscale and color images).
    - Sharpen images to match the appearance of the originals, and compensate for variations in originals and the digitization process (grayscale and color images).

The following sections address various types of image adjustments that we feel are often needed and are appropriate. The amount of adjustment needed to bring images to a common rendition will vary depending on the original, on the scanner/digital camera used, and on the image processing applied during digitization (the specific scanner or camera settings).

6.2 Color Correction and Tonal Adjustments

Many tools exist within numerous applications for correcting image color and adjusting the tonal scale. The actual techniques of using them are described in many excellent texts entirely devoted to the subject. There are, however, some general principles that should be followed.

Properly calibrated systems for reflective capture should require little post-scan correction. This guidance would always apply to color and black and white film negatives for appropriate rendering.

- As much as possible, depending on hardware and software available, images should be captured and color corrected in high bit depth.
- Images should be adjusted to render correct highlights and shadows usually neutral (but not always) of appropriate brightness, and without clipping detail. Also, other neutral colors in the image should not have a color cast (see aimpoint discussion above).
- Avoid tools with less control that act globally, such as brightness and contrast, and that are more likely to compromise data, such as clipping tones.
- Use tools with more control and numeric feedback, such as levels and curves.

- Despite the desire and all technological efforts to base adjustments on objective measurements, some amount of subjective evaluation may be necessary, and will depend upon operator skill and experience.
- Do not rely on "auto correct" features. Most automatic color correction tools are designed to work with color photographic images and the programmers assumed a standard tone and color distribution that is not likely to match your images. This is particularly true for scans of text documents, maps, plans, etc.
- Color correction and tonal adjustments can only be accurately performed on a graphic workstation with a calibrated monitor capable of displaying the appropriate color space, and under controlled environmental conditions.

6.3 Cropping

We recommend the entire object be scanned, without cropping. A small border should be visible around the entire document or photographic image. Placement of documents on flatbed scanners will require the originals to be away from platen edge. Including the edge of the object in the digital image provides an assurance that the entire image was scanned.

For photographic records - If there is important information on a mount or in the border of a negative, then scan the entire mount and the entire negative including the full border. Notch codes in sheet film are often considered important to retain. Typical film carriers cover a small portion of the film area, ruling out imaging all the way to the edge of the film. The alternate approach is to image between sheets of glass, introducing the possibility of Newton's rings, dust and other artifacts. Imaging without glass generally will result in a superior scan, and is therefore preferred if possible.

Crop with a border for whole artifact information and crop inside edges for access.

6.4 Compensating for Minor Deficiencies

Scanning at higher than the desired resolution and resampling to the final resolution can minimize certain types of minor imaging deficiencies such as minor color channel misregistration, minor chromatic aberration, and low to moderate levels of image noise. Conceptually, the idea is to bury the defects in the fine detail of the higher resolution scan, which are then averaged out when the pixels are resampled to a lower resolution. This approach should not be used as a panacea for poorly performing scanners/digital cameras. Generally it is better to invest in higher quality digitization equipment. Before using this approach in production, tests should be run to determine if there is sufficient improvement in the final image quality to justify the extra time and effort. Similarly, for some flatbed and planetary scanners, it can be better to find and utilize the sweet spots for resolution, where the mechanics of the system operate at peak capability.

6.5 Stitching

Often originals cannot be captured at the desired resolution with one capture, even with the highest resolution devices. In addition, lenses have limited resolving capability when tasked with imaging very large and detailed materials like maps. The practical answer is to capture the image in multiple overlapping sections, imaging small areas of the original with the full area of the sensor. The image segments are then reassembled in software that "stitches" the segments back together. This technique can achieve images with resolution limited only by the limits of digital file sizes. Even this limit can be extended by breaking up the files to logical segments appropriate for the final output device.

This technique requires stability of all elements of the imaging system including even lighting, precise movement and positioning of the image between segments, and consistent exposure. When done properly, the results can be exceptional and reveal every detail in the original without breaking up under magnification. This technique is not new, it traces its roots to optical techniques used in the film era. In the era before digital printing, extreme enlargements were made in mural strip sections, each with their own large format negative of just the area related to that segment. This technique reduced the magnification required, and also reduced the grain of the film on the final mural. In the digital era, the highest resolution scan devices also use this technique. Drum scanners capture one pixel at a time and place them next to each other in columns and rows. The highest resolution professional flatbed scanners focus their sensors on a small section of the image and capture the whole in a series of tiles that are then stitched together in the scanner software.

This same technique can be accomplished using a digital camera, capturing small portions of an original a section at a time, and reassembling the whole in software. The smaller (tile) images should be captured with overlap to ensure stitching is possible and no content is lost. Best practice is to capture 20% overlap between adjoining images. Computers and programs with more processing power will produce better stitching results.

When using stitching, the set of individual stitches should be considered the archival master. The assembled version is considered the production master.

6.6 Scanning Text

Guidelines have been established in the digital library community that address the most basic requirements for preservation digitization of text-based materials. This level of reproduction is defined as a "faithful rendering of the underlying source document" as long as the images meet certain criteria. These criteria include completeness, image quality (tonality and color), and the ability to reproduce pages in their correct (original) sequence. As a faithful rendering, a digital master will also support production of a printed page facsimile that is a legible facsimile when produced in the same size as the original (that is 1:1). See the Digital Library Federation's *Benchmark for Faithful Digital Reproductions of Monographs and Serials* at http://www.diglib.org/standards/bmarkfin.htm for a detailed discussion.

6.7 Optical Character Recognition

Optical Character Recognition (OCR) is the process of converting a raster image of text into searchable electronic text. FADGI three-star imaging generally produces image files capable of high quality conversion, but given the variety of OCR software available and the variability of source materials, testing should be done to determine the most efficient imaging settings. Digital images should be created to a quality level that will facilitate OCR conversion to a specified accuracy level. This should not, however, compromise the quality of the images to meet the quality index as stated in this document.

Chapter 7: Technical Overview

This chapter provides an overview of technical criteria and aspects of cultural heritage imaging.

7.1 Spatial Resolution

Spatial resolution determines the amount of information in a raster image file in terms of the number of picture elements or pixels per unit of measurement, but it does not define or guarantee the quality of the information. Spatial resolution defines how finely or widely spaced the individual pixels are from each other. The higher the spatial resolution, the more finely pixels are spaced and the higher the number of pixels overall. The lower the spatial resolution, the more widely pixels are spaced and the fewer the number of pixels overall.

Spatial resolution is measured as pixels per inch or PPI; pixels per millimeter or pixels per centimeter are also used. Resolution is often referred to as dots per inch or DPI. In common usage, the terms PPI and DPI are used interchangeably. Since raster image files are composed of pixels, technically PPI is a more accurate term and is used in this document (one example in support of using the PPI term is that Adobe Photoshop software uses the pixels per inch terminology). DPI is the appropriate term for describing printer resolution (actual dots vs. pixels); however, DPI is often used in scanning and image processing software to refer to spatial resolution and this usage is an understandable convention.

The spatial resolution and the image dimensions determine the total number of pixels in the image; an 8"x10" photograph scanned at 100 ppi produces an image that has 800 pixels by 1000 pixels or a total of 800,000 pixels. The numbers of rows and columns of pixels, or the height and width of the image in pixels as described in the previous sentence, is known as the pixel array.

The image file size, in terms of data storage, is proportional to the spatial resolution (the higher the resolution, the larger the file size for a set document size) and to the size of the document being scanned (the larger the document, the larger the file size for a set spatial resolution). Increasing resolution increases the total number of pixels, resulting in a larger image file. Scanning larger documents produces more pixels resulting in larger image files.

Higher spatial resolution provides more pixels, and generally will render more fine detail of the original in the digital image, but not always. The actual rendition of fine detail is more dependent on the spatial frequency response (SFR) of the scanner or digital camera (see Quantifying Scanner/Digital Camera Performance below), the image processing applied, and the characteristics of the item being scanned.

7.2 Signal Resolution

Bit depth or signal resolution, sometimes called tonal resolution, defines the maximum number of shades and/or colors in a digital image file, but does not define or guarantee the quality of the information.

In a 1-bit file each pixel is represented by a single binary digit (either a 0 or 1), so the pixel can be either black or white. There are only two possible combinations or $2^1 = 2$.

A common standard for grayscale and color images is to use 8-bits (eight binary digits representing each pixel) of data per channel and this provides a maximum of 256 shades per channel ranging from black to white; $2^8 = 256$ possible combinations of zeroes and ones.

High-bit or 16-bits (16 binary digits representing each pixel) per channel images can have a greater number of shades compared to 8-bit per channel images, a maximum of over 65,000 shades vs. 256 shades; 2^{16} - 65,536 possible combinations of zeroes and ones.

Well done 8-bits per channel imaging will meet most needs - with a limited ability for major corrections, transformations, and re-purposing. Gross corrections of 8-bit per channel images may cause shades to drop out of the image, creating a posterization effect due to the limited number of shades.

High-bit images can match the effective shading and density range of photographic originals (assuming the scanner is actually able to capture the information), and, due to the greater shading (compared to 8-bits per channel), may be beneficial when re-purposing images and when working with images that need major or excessive adjustments to the tone distribution and/or color balance.

7.3 Color Mode

Grayscale image files consist of a single channel, commonly either 8-bits (256 levels) or 16-bits (65,536 levels) per pixel with the tonal values ranging from black to white. Color images consist of three or more grayscale channels that represent color and brightness information. Common color modes include RGB (red, green, blue), CMYK (cyan, magenta, yellow, black), and L*a*b* (lightness, red-green, blue-yellow). The channels in color files may be either 8-bits (256 levels) or 16-bits (65,536 levels). Display and output devices mathematically combine the numeric values from the multiple channels to form full color pixels, ranging from black to white and to full colors.

RGB represents an additive color process: red, green, and blue light are combined to form white light. This is the approach commonly used by computer monitors and televisions, film recorders that image onto photographic film, and digital printers/enlargers that print to photographic paper. RGB files have three color channels: 3 channels x 8-bits = 24-bit color file or 3 channels x 16-bits = 48-bit color. All scanners and digital cameras create RGB files by sampling for each pixel the amount of light passing through red, green, and blue filters that is being reflected or transmitted by the item or scene being digitized. Black is represented by combined RGB levels of 0-0-0, and white is represented by combined RGB levels of 255-255-255. This is based on 8-bit imaging and 256 levels from 0 to 255; this convention is used for 16-bit imaging as well, despite the greater number of shades. All neutral colors have equal levels in all three color channels. A pure red color is represented by levels of 255-0-0, pure green by 0-255-0, and pure blue by 0-0-255.

CMYK files are an electronic representation of a subtractive process: cyan (C), magenta (M), and yellow (Y) are combined to form black. CMYK mode files are used for prepress work and include a fourth channel representing black ink (K). The subtractive color approach is used in printing presses (four color printing), color inkjet, and laser printers (four color inks, many photo inkjet printers now have more colors), and almost all traditional color photographic processes (red, green, and blue sensitive layers that form cyan, magenta, and yellow dyes).

L*a*b* color mode is a device independent color space that is matched to human perception: three channels representing lightness (L, equivalent to a grayscale version of the image), red and green information (A), and blue and yellow information (B). One benefit of L*a*b* mode is that it is matched to human perception, and also L*a*b* mode does not require color profiles (see section on color management). Disadvantages of L*a*b* include the potential loss of information in the conversion from the RGB mode files from scanners and digital cameras, the need to have high-bit data, and the fact that few applications and file formats support it.

Avoid saving files in CMYK mode. CMYK files have a significantly reduced color gamut (see section on color management) and are not suitable for master image files for digital imaging projects involving holdings/collections in cultural institutions. The conversion from RGB to CMYK involves the replacement of a portion of the neutral color with black (K). This conversion is not reversible back to RGB without the loss of color accuracy.

While theoretically L*a*b* may have benefits, at this time we feel that RGB files produced to the color and tone reproduction described in these *Guidelines* and saved with an appropriate ICC profile, are the most practical option for master files and are relatively device independent. We acknowledge that the workflow described in these *Guidelines* to produce RGB master files may incur some level of loss of data; however, we believe the benefits of using RGB files brought to a common rendering outweigh the minor loss.

7.4 Quantifying Scanner/Digital Camera Performance

Much effort has gone into quantifying the performance of scanners and digital cameras in an objective manner. The following tests are used to check the capabilities of digitization equipment, and provide information on how to best use the equipment.

Even when digitization equipment is assessed as described below, it is still necessary to have knowledgeable and experienced staff to evaluate images visually. At this time, it is not possible to rely entirely on the objective test measurements to ensure optimum image quality. It is still necessary to have staff with the visual literacy and technical expertise to do a good job with digitization and to perform quality control for digital images. This is true for the digitization of all types of original materials, but very critical for the digitization of photographic images in particular.

Also, these tests are useful when evaluating and comparing scanners and digital cameras prior to purchase. **Ask manufacturers and vendors for actual test results, rather than relying on the specifications provided in product literature, as performance claims in product literature are often overstated**. If test results are not available, then try to scan test targets during a demonstration and analyze the target files with digital image conformance evaluation or have them reviewed by an analysis service.

During digitization projects, tests should be performed on a routine basis to ensure scanners and digital cameras/copy systems are performing optimally. Again, if it is not possible to analyze the tests in-house, then consider having a service perform the analyses on the resulting image files.

The following standards either are available or are in development. Digital image conformance evaluation should cover all of these elements. These are noted only as a reference for those who are interested in an advanced understanding of the standards.

Terminology	ISO 12231
Opto-Electronic Conversion Function	ISO 14524
Resolution: Still Picture Cameras	ISO 12233
Resolution: Print Scanners	ISO 16067-1
Resolution: Film Scanners	ISO 16067-2
Noise: Still Picture Cameras	ISO 15739

Dynamic Range: Film Scanners	ISO 21550
Best Practices for Digital Image Capture of Cultural Heritage Materials	ISO 19263
Image Quality Analysis –Part 1 Reflective Originals	ISO 19264

These standards can be purchased from ISO at http://www.iso.ch or from IHS Global at http://global.ihs.com. At this time, test methods and standards do not exist for all testing and device combinations. However, many tests are applicable across the range of capture device types and are cited in the existing standards as normative references.

Other test methods may be used to quantify scanner/digital camera performance. We anticipate there will be additional standards and improved test methods developed by the group working on the above standards.

No digitization equipment or system is perfect. They all have trade-offs in image quality, speed, and cost. The engineering of scanners and digital cameras represents a compromise, and for many markets image quality is sacrificed for higher speed and lower cost of equipment. Many document and book scanners, office scanners (particularly inexpensive ones), and high-speed scanners (all types) may not meet the limits specified, particularly for properties like image noise. Also, many office and document scanners are set at the default to force the paper of the original document to pure white in the image, clipping all the texture and detail in the paper (not desirable for most originals in collections of cultural institutions). These scanners will not be able to meet the desired tone reproduction without recalibration (which may not be possible), without changing the scanner settings (which may not overcome the problem), or without modification of the scanner and/or software (not easily done).

7.4.1 Test Frequency and Equipment Variability

After equipment installation and familiarization with the hardware and software, an initial performance capability evaluation should be conducted using a digital image conformance evaluation system to establish a baseline for each specific digitization device.

Many scanners can be used both with the software/device drivers provided by the manufacturer and with third-party software/device drivers. However, it is best to characterize the device using the specific software/device drivers to be used for production digitization. Also, performance can change dramatically (and not always for the better) when software/device drivers are updated; therefore, it is best to characterize the device after every update.

Digital image conformance evaluation testing should be performed at the beginning of each work day, or at the start of each batch, whichever comes first. Testing at the beginning and at the end of each batch to confirm that digitization was consistent for the entire batch is desirable. Scanner/digital camera performance will vary based on actual operational settings. Tests can be used to optimize the scanner/camera settings. The performance of individual scanners and digital cameras will vary over time. Also, the performance of different units of the same model scanner/camera will vary. Test every individual scanner/camera with the specific software/device driver combination(s) used for production. Perform digital image conformance test(s) any time there is an indication of a problem. Compare these results to past performance through a cumulative database. If large variability is noted from one session to the next for given scanner/camera settings, attempt to rule out operator error first.

7.4.2 Reference Targets

FADGI Recommendations

Include reference targets in each image of originals being scanned including, at a minimum, a gray scale, color reference, and an accurate dimensional scale.

- If a target is included in each image, consider making access derivatives from the production masters that have the reference target(s) cropped out. This will reduce file size for the access files and present an uncluttered appearance to the images presented.
- All types of tone and color targets should be replaced on a routine basis. As the targets are used they will accumulate dirt, scratches, and other surface marks that reduce their usability.

- Target images should be captured during the same session and under the exact same conditions as the images of the object.
- Once conformance is established, do not make changes to the imaging workflow. Reference targets should be used to conduct new testing every time a change in settings or conditions is introduced.
- Transmission targets are available from a variety of sources for color references, but only B&W targets are currently available for analysis with digital image conformance evaluation.

Placement of Target

Position the target close to, but clearly separated from, the originals being scanned. There should be enough separation to allow easy cropping of the image of the original to remove the target(s) if desired, but not so much separation between the original and target(s) that it dramatically increases the file size.

- If it fits, orient the target(s) along the short dimension of originals. That will produce smaller file sizes compared to having the target(s) along the long dimension. For the same document, a more rectangular shaped image file is smaller than a squarer image.
- For digital copy photography set-ups using digital cameras when digitizing items that have depth, it is important to make sure all reference targets are on the same level as the image plane. For example, when digitizing a page in a thick book, make sure the reference targets are at the same height/level as the page being scanned.

Illumination

Make sure that the illumination on the targets is uniform in comparison to the lighting of the item being scanned. Avoid hot spots and/or shadows on the targets. Position targets to avoid reflections.

- If the originals are digitized under glass, place the tone and color reference targets under the glass as well.
- If originals are encapsulated or sleeved with polyester film, place the tone and color reference targets into a polyester sleeve.

Chapter 8: Metadata

This section of the *Guidelines* serves as a general discussion of metadata rather than a recommendation of specific metadata element sets.

Although there are many technical parameters discussed in these guidelines that define a high-quality master image file, we do not consider an image to be of high quality unless metadata is associated with the file. Metadata makes possible several key functions: the identification, management, access, use, and preservation of a digital resource. Therefore metadata is directly associated with most of the steps in a digital imaging project workflow. Although it can be costly and time-consuming to produce, metadata adds value to master image files. Images without sufficient metadata are at greater risk of being lost.

8.1 Application Profiles

No single metadata element set or standard will be suitable for all projects or all collections. Likewise, different original source formats (text, image, audio, video, etc.) and different digital file formats may require varying metadata sets and depths of description. Element sets should be adapted to fit requirements for particular materials, business processes, and system capabilities.

Because no single element set will be optimal for all projects, implementations of metadata in digital projects are beginning to reflect the use of “application profiles,” defined as metadata sets that consist of data elements drawn from different metadata schemas, which are combined, customized, and optimized for a particular local application or project. This “mixing and matching” of elements from different schemas allows for more useful metadata to be implemented at the local level while adherence to standard data values and structures is still maintained. Locally-created elements may be added as extensions to the profile, data elements from existing schemas might be modified for specific interpretations or purposes, or existing elements may be mapped to terminology used locally.

8.2 Data or Information Models

Because of the likelihood that heterogeneous metadata element sets, data values, encoding schemes, and content information (different source and file formats) will need to be managed within a digital project, it is good practice to put all of these pieces into a broader context at the outset of any project in the form of a data or information model. A model can help to define the types of objects involved and how and at what level they will be described (i.e., are descriptions hierarchical in nature, will digital objects be described at the file or item level as well as at a higher aggregate level, how are objects and files related, what kinds of metadata will be needed for the system, for retrieval and use, for management, etc.), as well as document the rationale behind the different types of metadata sets and encodings used. A data model informs the choice of metadata element sets, which determine the content values, which are then encoded in a specific way (in relational database tables or an XML document, for example).

8.3 Levels of Description

Although there is benefit to recording metadata on the item level to facilitate more precise retrieval of images within and across collections, we realize that this level of description is not always practical. Different projects and collections may warrant more in-depth metadata capture than others. A deep level of description at the item level, for example, is not usually accommodated by traditional archival descriptive practices. The functional purpose of metadata often determines the amount of metadata that is needed. Identification and retrieval of digital images may be accomplished using a very small amount of metadata. However, management of and preservation services performed on digital images will require more finely detailed metadata – particularly at the technical level, in order to render the file; and at the structural level, in order to describe the relationships among different files and versions of files.

Metadata creation requires careful analysis of the resource at hand. Although there are current initiatives aimed at automatically capturing a given set of values, we believe that metadata input is still largely a manual process and will require human intervention at many points in the object's lifecycle to assess the quality and relevance of metadata associated with it.

8.4 Common Metadata Types

Several categories of metadata are associated with the creation and management of image files. The following metadata types are the ones most commonly implemented in imaging projects. Although these categories are defined separately below, there is not always an obvious distinction between them since each type contains elements that are both descriptive and administrative in nature. These types are commonly broken down by what functions the metadata supports. In general, the types of metadata listed below, except for descriptive, are usually found "behind the scenes" in databases rather than in public access systems. As a result, these types of metadata tend to be less standardized and more aligned with local requirements. For an overview of different metadata types, standards, and applications, see the Diane Hillmann's presentations, available at http://managemetadata.org/msa_r2/, and a course manual available at https://www.loc.gov/catworkshop/courses/metadatastandards/pdf/MSTraineeManual.pdf.

The Digital Curation Centre has also published information on this topic, including an additional overview of metadata types with examples of standards available at https://www.dcc.ac.uk/guidance/briefing-papers/standards-watch-papers/what-are-metadata-standards. An introduction to using metadata standards in digital curation can be found at https://www.dcc.ac.uk/guidance/briefing-papers/standards-watch-papers/using-metadata-standards.

8.4.1 Descriptive

Descriptive metadata refers to information that supports discovery and identification of a resource (the who, what, when, and where of a resource). It describes the content of the resource, associates various access points, and describes how the resource is related to other resources intellectually or within a hierarchy. In addition to bibliographic information, it may also describe physical attributes of the resource such as media type, size, and condition. Descriptive metadata is usually highly structured and often conforms to one or more standardized, published schemas such as Dublin Core or MARC. Controlled vocabularies, thesauri, or authority files are commonly used to maintain consistency across the assignment of access points. Descriptive information is usually stored outside of the image file, often in separate catalogs or databases from technical information about the image file.

Although descriptive metadata may be stored elsewhere, it is recommended that some basic descriptive metadata (such as a caption or title) accompany the structural and technical metadata captured during production. The inclusion of this metadata can be useful for identification of files or groups of related files during quality review and other parts of the workflow or for tracing the image back to the original.

Descriptive metadata is not specified in detail in this document. However, we recommend the use of the Dublin Core Metadata Element1[8] set to capture minimal descriptive metadata information where metadata in another formal data standard does not exist. Metadata should be collected directly in Dublin Core. If it is not used for direct data collection, a mapping to Dublin Core elements is recommended. A mapping to Dublin Core from a richer, local metadata scheme already in use may also prove helpful for data exchange across other projects utilizing Dublin Core. Not all Dublin Core elements are required in order to create a valid Dublin Core record.

Any local fields that are significant within the context of a particular project should also be captured to supplement Dublin Core fields so that valuable information is not lost. We anticipate that selection of metadata elements will come from more than one preexisting element set – elements can always be tailored to specific formats or local needs. Projects should support a modular approach to designing metadata to fit the specific requirements of the project. Standardizing on Dublin Core supplies baseline metadata that provides access to files. However, this should not exclude richer metadata that extends beyond the Dublin Core set, if available.

For large-scale digitization projects, only minimal metadata may be affordable to record during capture and is likely to consist of linking image identifiers to page numbers and indicating major structural divisions or anomalies of the resource (if applicable) for text documents. For photographs, capturing caption information or keywords, if any, and a local identifier for the original photograph is ideal. For other non-textual materials, such as posters and maps, descriptive information taken directly from the item being imaged as well as a local identifier should be captured. If keying of captions into a database is prohibitive, scan captions as part of the image itself if possible. Although this information will not be searchable, it will serve to provide some basis of identification for the subject matter of the photograph. Recording of identifiers is important for uniquely identifying resources and is necessary for locating and managing them. It is likely that digital images will be associated with more than one identifier – for the image itself, for metadata or database records that describe the image, and for reference back to the original.

8.4.2 Administrative

The Dublin Core set does not provide for administrative, technical, or highly structured metadata about different document types. Administrative metadata comprises both technical and preservation metadata and is generally used for internal management of digital resources. Administrative metadata may include information about rights and reproduction or other access requirements, selection criteria or archiving policy for digital content, audit trails or logs created by a digital asset management system, persistent identifiers, methodology or documentation of the imaging process, or information about the source materials being scanned. In general, administrative metadata is informed by the local needs of the project or institution and is defined by project-specific workflows. Administrative metadata may also encompass repository-like information, such as billing information or contractual agreements for deposit of digitized resources into a repository.

For additional information, see the California Digital Library's *Guidelines for Digital Objects* at https://cdlib.org/wp-content/uploads/2021/06/cdl_gdo_v2021.pdf. The Library of Congress has defined a data dictionary for various formats in the context of METS, Data Dictionary for Administrative Metadata for

[8] Dublin Core Metadata Initiative, (https://www.dublincore.org/specifications/dublin-core/dcmi-terms/). The Dublin Core element set is characterized by simplicity in creation of records, flexibility, and extensibility. It facilitates description of all types of resources and is intended to be used in conjunction with other standards that may offer fuller descriptions in their respective domains.

Audio, Image, Text, and Video Content to Support the Revision of Extension Schemas for METS, available at http://lcweb.loc.gov/rr/mopic/avprot/extension2.html.

8.4.3 Rights

Although metadata regarding rights management information is briefly mentioned above, it encompasses an important piece of administrative metadata that deserves further discussion. Rights information plays a key role in the context of digital imaging projects and will become more and more prominent in the context of preservation repositories, as strategies to act upon digital resources in order to preserve them may involve changing their structure, format, and properties. Rights metadata will be used by humans to identify rights holders and legal status of a resource, and also by systems that implement rights management functions in terms of access and usage restrictions.

Because rights management and copyright are complex legal topics, legal counsel should be consulted for specific guidance and assistance. The following discussion is provided for informational purposes only and should not be considered specific legal advice.

At a minimum, rights-related metadata should include the legal status of the record; a statement on who owns the physical and intellectual aspects of the record; contact information for these rights holders; as well as any restrictions associated with the copying, use, and distribution of the record. To facilitate bringing digital copies into future repositories, it is desirable to collect appropriate rights management metadata at the time of creation of the digital copies. At the very least, digital versions should be identified with a designation of copyright status, such as: “public domain;” “copyrighted” (and whether clearance/permissions from rights holder has been secured); “unknown;” “donor agreement/ contract;” etc.

Preservation metadata dealing with rights management in the context of digital repositories will likely include detailed information on the types of actions that can be performed on data objects for preservation purposes and information on the agents or rights holders that authorize such actions or events.

For an example of rights metadata in the context of libraries and archives, a rights extension schema has also been added to the Metadata Encoding and Transmission Standard (METS), which documents metadata about the intellectual rights associated with a digital object. This extension schema contains three components: a rights declaration statement; detailed information about rights holders; and context information, which is defined as “who has what permissions and constraints within a specific set of circumstances.” The schema is available at https://www.loc.gov/standards/rights/METSRights.xsd.

For additional information on rights management, see:

June M. Besek, Copyright Issues Relevant to the Creation of a Digital Archive: A Preliminary Assessment, January 2003 at http://www.clir.org/pubs/reports/pub112/contents.html;

Karen Coyle, Rights Expression Languages, A Report to the Library of Congress, February 2004, available at https://www.loc.gov/standards/relreport.pdf;

MPEG-21 Overview v.5 contains a discussion on intellectual property and rights at https://www.mpegstandards.org/standards/MPEG-21/;

Mary Minow, “Library Digitization Projects: Copyrighted Works that have Expired into the Public Domain” at http://www.librarylaw.com/DigitizationTable.htm;

For a comprehensive discussion on libraries and copyright, see: Mary Minow, *Library Digitization Projects and Copyright* at https://www.llrx.com/2002/06/library-digitization-projects-and-copyright-part-i-introduction-and-overview/.

8.4.4. Technical

Technical metadata refers to information that describes attributes of the digital image (not the analog source of the image) and helps to ensure that images will be rendered accurately. It supports content preservation by providing information needed by applications to use the file and to successfully control the transformation or migration of images across or between file formats. Technical metadata also describes the image capture process and technical environment, such as hardware and software used to scan images, as well as file format-specific information, image quality, and information about the source object being scanned, which may influence scanning decisions. Technical metadata helps to ensure consistency across a large number of files by enforcing standards for their creation. At a minimum, technical metadata should capture the information necessary to render, display, and use the resource.

Technical metadata is characterized by information that is both objective and subjective – attributes of image quality that can be measured using objective tests as well as information that may be used in a subjective assessment of an image's value. Although tools for automatic creation and capture of many objective components are badly needed, it is important to determine what metadata should be highly structured and useful to machines, as opposed to what metadata would be better served in an unstructured, free-text note format. The more subjective data is intended to assist researchers in the analysis of a digital resource or imaging specialists and preservation administrators in determining long-term value of a resource.

In addition to the digital image, technical metadata will also need to be supplied for the metadata record itself if the metadata is formatted as a text file or XML document or METS document, for example. In this sense, technical metadata is highly recursive but necessary for keeping both images and metadata understandable over time.

Requirements for technical metadata will differ for various media formats. For digital still images, we refer to the *ANSI/NISO Z39.87 Data Dictionary - Technical Metadata for Digital Still Images* available from the NISO website at http://www.niso.org/publications/ansiniso-z3987-2006-r2017-data-dictionary-technical-metadata-digital-still-images. It is a comprehensive technical metadata set based on the Tagged Image File Format (TIFF) specification, and makes use of the data that is already captured in file headers. It also contains metadata elements important to the management of image files that are not present in header information, but that could potentially be automated from scanner/camera software applications. An XML schema for the NISO technical metadata has been developed at the Library of Congress called MIX (Metadata in XML), which is available at http://www.loc.gov/standards/mix/. MIX version 2.0 is now the current version of MIX.

See the TIFF 6.0 Specification at https://www.adobe.io/content/dam/udp/en/open/standards/tiff/TIFF6.pdf as well as additional information on TIFF 6.0 at https://www.loc.gov/preservation/digital/formats/fdd/fdd000022.shtml.

8.4.4.1 Embedded Metadata

Although embedded metadata is mostly about "where" metadata is stored, it seems in some ways to be a subset of technical metadata as it primarily refers to attributes about the digital image and the creation of the digital image. See http://www.digitizationguidelines.gov/guidelines/digitize-tiff.html.

In some cases, metadata (of any type, including technical) will not be embedded in the digital image file, but in a separate or "sidecar" file. Sidecar files are used when the file format does not support embedding metadata from a specific standard (such as XMP – see below), to protect metadata from being altered by editing software, when applications do not support certain raw file formats, and/or to enable faster previewing of images.

8.4.5 Structural

Structural metadata describes the relationships between different components of a digital resource. It ties the various parts of a digital resource together in order to make a useable, understandable whole. One of the primary functions of structural metadata is to enable display and navigation, usually via a page-turning application, by indicating the sequence of page images or the presence of multiple views of a multi-part item. In this sense, structural metadata is closely related to the intended behaviors of an object. Structural metadata is very much informed by how the images will be delivered to the user as well as how they will be stored in a repository system in terms of how relationships among objects are expressed.

Structural metadata often describes the significant intellectual divisions of an item (such as chapter, issue, illustration, etc.), and correlates these divisions to specific image files. These explicitly labeled access points help to represent the organization of the original object in digital form. This does not imply, however, that the digital form must always imitate the organization of the original – especially for non-linear items, such as folded pamphlets. Structural metadata also associates different representations of the same resource together, such as master image files with their derivatives, or different sizes, views, or formats of the resource.

Example structural metadata might include whether the resource is simple or complex (multi-page, multi-volume, has discrete parts, contains multiple views); what the major intellectual divisions of a resource are (table of contents, chapter, musical movement); identification of different views (double-page spread, cover, detail); the extent (in files, pages, or views) of a resource and the proper sequence of files, pages and views; as well as different technical (file formats, size), visual (pre- or post-conservation treatment), intellectual (part of a larger collection or work), and use (all instances of a resource in different formats – TIFF files for display, PDF files for printing, OCR file for full text searching) versions.

File names and organization of files in system directories comprise structural metadata in its barest form. Since meaningful structural metadata can be embedded in file and directory names, consideration of where and how structural metadata is recorded should be done upfront.

No widely adopted standards for structural metadata exist since most implementations of structural metadata are at the local level and are very dependent on the object being scanned and the desired functionality in using the object. Most structural metadata is implemented in file naming schemes and/or in spreadsheets or databases that record the order and hierarchy of the parts of an object so that they can be identified and reassembled into their original form.

The Metadata Encoding and Transmission Standard (METS) is often discussed in the context of structural metadata, although it is inclusive of other types of metadata as well. METS provides a way to associate metadata with the digital files it describes and to encode the metadata and the files in a standardized manner using XML. METS requires structural information about the location and organization of related digital files to be included in the METS document. Relationships between different representations of an object as well as relationships between different hierarchical parts of an object can be expressed. METS brings together a variety of metadata about an object all into one place by allowing the encoding of descriptive, administrative, and structural metadata. Metadata and content information can either be wrapped together within the METS document or pointed to from the METS document, if they exist in externally disparate systems. METS also supports extension schemas for descriptive and administrative metadata to accommodate a wide range of metadata implementations. Beyond associating metadata with digital files, METS can be used as a data transfer syntax so objects can easily be shared; as a Submission Information Package, an Archival Information Package, and a Dissemination Information Package in an OAIS-compliant repository (see below); and also as a driver for applications, such as a page turner, by associating certain behaviors with digital files so that they can be viewed, navigated, and used. Because METS is primarily concerned with structure, it works best with “library-like” objects in establishing relationships among multi-page or multi-part objects, but it does not apply as well to hierarchical relationships that exist in collections within an archival context.

See http://www.loc.gov/standards/mets/ for more information on METS.

8.4.6 Behavior

Behavior metadata is often referred to in the context of a METS object. It associates executable behaviors with content information that define how a resource should be utilized or presented. Specific behaviors might be associated with different genres of materials (books, photographs, PowerPoint presentations) as well as with different file formats. Behavior metadata contains a component that abstractly defines a set of behaviors associated with a resource as well as a “mechanism” component that points to executable code (software applications) that then performs a service according to the defined behavior. The ability to associate behaviors or services with digital resources is one of the attributes of a METS object and is also part of the “digital object architecture” of the Fedora digital repository system. See http://www.fedora.info/ for discussion of Fedora and digital object behaviors.

8.4.7 Preservation

Preservation metadata encompasses all information necessary to manage and preserve digital assets over time. Preservation metadata is usually defined in the context of the OAIS reference model (Open Archival Information System) and is often linked to the functions and activities of a repository. It differs from technical metadata in that it documents processes performed over time (events or actions taken to preserve data and the outcomes of these events) as opposed to explicitly describing provenance (how a digital resource was created) or file format characteristics, but it does encompass all types of the metadata mentioned above, including rights information. Although preservation metadata draws on information recorded earlier (technical and structural metadata would be necessary to render and reassemble the resource into an understandable whole), it is most often associated with analysis of and actions performed on a resource after submission to a repository. Preservation metadata might include a record of changes to the resource, such as transformations or conversions from format to format, or indicate the nature of relationships among different resources.

Preservation metadata is information that will assist in preservation decision-making regarding the long-term value of a digital resource and the cost of maintaining access to it and will help to both facilitate archiving strategies for digital images as well as support and document these strategies over time. Preservation metadata is commonly linked with digital preservation strategies such as migration and emulation, as well as more "routine" system-level actions such as copying, backup, or other automated processes carried out on large numbers of objects. These strategies will rely on all types of pre-existing metadata and will also generate and record new metadata about the object. It is likely that this metadata will be both machine-readable and "human-readable" at different levels to support repository functions as well as preservation policy decisions related to these objects.

In its close link to repository functionality, preservation metadata may reflect or even embody the policy decisions of a repository; but these are not necessarily the same policies that apply to preservation and reformatting in a traditional context. The extent of metadata recorded about a resource will likely have an impact on future preservation options to maintain it. Current implementations of preservation metadata are repository- or institution-specific. A digital asset management system may provide some basic starter functionality for low-level preservation metadata implementation but not to the level of a repository modeled on the OAIS.

See also *A Metadata Framework to Support the Preservation of Digital Objects* at https://www.oclc.org/content/dam/research/activities/pmwg/pm_framework.pdf and

Preservation Metadata for Digital Objects: A Review of the State of the Art at https://www.oclc.org/content/dam/research/activities/pmwg/presmeta_wp.pdf, both by the OCLC/RLG Working Group on Preservation Metadata, for excellent discussions of preservation metadata in the context of the OAIS model. The international working group behind PREMIS, or "Preservation Metadata: Implementation Strategies," has developed best practices for implementing preservation metadata and has published a recommended core set of preservation metadata in their Data Dictionary for Preservation Metadata, as well as an XML schema. Their work can be found at http://www.loc.gov/standards/premis/.

8.4.8 Tracking

Tracking metadata is used to control or facilitate the particular workflow of an imaging project during different stages of production. Elements might reflect the status of digital images as they go through different stages of the workflow (batch information and automation processes, capture, processing parameters, quality control, archiving, identification of where/media on which files are stored). This is primarily internally-defined metadata that serves as documentation of the project and may also serve also serve as a statistical source of information to track and report on progress of image files. Tracking metadata may exist in a database or via a directory/folder system.

8.4.9 Meta-Metadata

Although this information is difficult to codify, it usually refers to metadata that describes the metadata record itself, rather than the object it is describing or to high-level information about metadata "policy" and procedures, most often on the project level. Meta-metadata documents information such as who records the metadata, when and how it gets recorded, where it is located, what standards are followed, and who is responsible for modification of metadata and under what circumstances.

It is important to note that metadata files yield "master" records as well. These non-image assets are subject to the same rigor of quality control and storage as master image files. Provisions should be made for the appropriate storage and management of the metadata files over the long term.

8.5 Assessment of Metadata Needs for Imaging Projects

Before beginning any scanning, it is important to conduct an assessment both of existing metadata and metadata that will be needed in order to develop data sets that fit the needs of the project. The following questions frame some of the issues to consider:

- *Does metadata already exist in other systems (database, bibliographic record, finding aid, on item itself) or in structured formats (Dublin Core, local database)?*

If metadata already exists, can it be automatically derived from these systems, pointed to from new metadata gathered during scanning, or does it require manual input? Efforts to incorporate existing metadata should be pursued. It is also extremely beneficial if existing metadata in other systems can be exported to populate a production database prior to scanning. This can be used as base information needed in production tracking or to link item level information collected at the time of scanning to metadata describing the content of the resource. An evaluation of the completeness and quality of existing metadata may need to be made to make it useful (e.g., what are the characteristics of the data content, how is it structured, can it be easily transformed?).

It is likely that different data sets with different functions will be developed and these sets will exist in different systems. However, efforts to link together metadata in disparate systems should be made so that it can be reassembled into something like a METS document, an Archival XML file for preservation, or a Presentation XML file for display, depending on what is needed. Metadata about digital images should be integrated into peer systems that already contain metadata about both digital and analog materials. By their nature, digital collections should not be viewed as something separate from non-digital collections. Access should be promoted across existing systems rather than building a separate stand-alone system.

- *Who will capture metadata?*

Metadata is captured by systems or by humans, and is intended for system or for human use. For example, certain preservation metadata might be generated by system-level activities such as data backup or copying. Certain technical metadata is used by applications to accurately render an image. In determining the function of metadata elements, it is important to establish whether this information is important for use by machines or by people. If it is information that is used and/or generated by systems, is it necessary to explicitly record it as metadata? What form of metadata is most useful for people? Most metadata element sets include less structured, note or comment-type fields that are intended for use by administrators and curators as data necessary for assessment of the provenance, risk of obsolescence, and value inherent to a particular class of objects. Any data, whether generated by systems or people that is necessary to understand a digital object, should be considered as metadata that may be necessary to formally record. But because of the high costs of manually generating metadata and tracking system-level information, the use and function of metadata elements should be carefully considered. Although some metadata can be automatically captured, there is no guarantee that this data will be valuable over the long term.

- *How will metadata be captured?*

Metadata capture will likely involve a mix of manual and automated entry. Descriptive and structural metadata creation is largely manual; some may be automatically generated through OCR processes to create indexes or full text; some technical metadata may be captured automatically from imaging software and devices; more sophisticated technical metadata, such as metadata that will be used to inform preservation decisions will require visual analysis and manual input.

An easy-to-use and customizable database or asset management system with a graphical and intuitive front end, preferably structured to mimic a project’s particular metadata workflow, is desirable and will make for more efficient metadata creation.

- *When will metadata be collected?*

Metadata is usually collected incrementally during the scanning process and will likely be modified over time. At least, start with a minimal element set that is known to be needed and add additional elements later if necessary.

Assignment of unique identifier or naming scheme should occur upfront. We also recommend that descriptive metadata be gathered prior to capture to help streamline the scanning process. It is usually much more difficult to add new metadata later on, without consultation of the originals. The unique file identifier can then be associated with a descriptive record identifier if necessary.

A determination of what structural metadata elements to record should also occur prior to capture, preferably during the preparation of materials for capture or during collation of individual items. Information about the hierarchy of the collection, the object types, and the physical structure of the objects should be recorded in a production database prior to scanning. The structural parts of the object can be linked to actual content files during capture. Most technical metadata is gathered at the time of scanning. Preservation metadata is likely to be recorded later on, upon ingest into a repository.

- *Where will the metadata be stored?*

Metadata can be embedded within the resource (such as an image header or file name), or can reside in a system external to the resource (such as a database), or both. Metadata can be also encapsulated with the file itself, such as with the Metadata Encoded Transmission Standard (METS). The choice of location of metadata should encourage optimal functionality and long-term management of the data.

Header data consists of information necessary to decode the image and has somewhat limited flexibility in terms of data values that can be put into the fields. Header information accommodates more technical than descriptive metadata (but richer sets of header data can be defined depending on the image file format). The advantage is that metadata remains with the file, which may result in more streamlined management of content and metadata over time. Several tags are saved automatically as part of the header during processing, such as dimensions, date, and color profile information, which can serve as base-level technical metadata requirements. However, methods for storing information in file format headers are very format-specific and data may be lost in conversions from one format to another. Also, not all applications may be able to read the data in headers. Information in headers should be manually checked to see if data has transferred correctly or has not been overwritten during processing. Just because data exists in headers does not guarantee that it has not been altered or has been used as intended. Information in headers should be evaluated to determine if it has value. Data from image headers can be extracted and imported into a database; a relationship between the metadata and the image must then be established and maintained.

Storing metadata externally to the image in a database provides more flexibility in managing, using, and transforming it and also supports multi-user access to the data, advanced indexing, sorting, filtering, and querying. It can better accommodate hierarchical descriptive information and structural information about multi-page or complex objects, as well as importing, exporting, and harvesting of data to external systems or other formats, such as XML. Because metadata records are resources that need to be managed in their own right, there is certainly benefit to maintaining metadata separately from file content in a managed system. Usually a unique identifier or the image file name is used to link metadata in an external system to image files in a directory.

We recommend that metadata be stored both in image headers as well as in an external database to facilitate migration and repurposing of the metadata. References between the metadata and the image files can be maintained via persistent identifiers. A procedure for synchronization of changes to metadata in both locations is also recommended, especially for any duplicated fields. This approach allows for metadata redundancy in different locations and at different levels of the digital object for ease of use (image file would not have to be accessed to get information; most header information would be extracted and added into an external system). Not all metadata should be duplicated in both places (internal and external to the file). Specific metadata is required in the header so that applications can interpret and render the file; additionally, minimal descriptive metadata such as a unique identifier or short description of the content of the file should be embedded in header information in case the file becomes disassociated from the tracking system or repository. Some applications and file formats offer a means to store metadata within the file in an intellectually structured manner, or allow the referencing of standardized schemes, such as Adobe XMP or the XML metadata boxes in the JPEG 2000 format. Otherwise, most metadata will reside in external databases, systems, or registries.

- *How will the metadata be stored?*

Metadata schemes and data dictionaries define the content rules for metadata creation but not the format in which metadata should be stored. Format may be determined partially by where the metadata is stored (file headers, relational databases, spreadsheets) as well as the intended use of the metadata – does it need to be human-readable, or indexed, searched, shared, and managed by machines? How the metadata is stored or encoded is usually a local decision. Metadata might be stored in a relational database or encoded in XML, such as in a METS document, for example.

Adobe's Extensible Metadata Platform (XMP) is another standardized format for describing where metadata can be stored and how it can be encoded, thus facilitating exchange of metadata across applications. The XMP specification provides both a data model and a storage model. Metadata can be embedded in the file in header information, stored in XML "packets" (these describe how the metadata is embedded in the file), or in accompanying sidecar files. XMP supports the capture of (primarily technical) metadata during content creation and modification and embeds this information in the file, which can then be extracted later into a digital asset management system or database or as an XML file. If an application is XMP enabled or aware (most Adobe products are), this information can be retained across multiple applications and workflows. XMP supports customization of metadata to allow for local field implementation using their Custom File Info Panels application. XMP supports a number of internal schemas, such as Dublin Core and EXIF (a metadata standard used for image files, particularly by digital cameras), as well as a number of external extension schemas. XMP does not guarantee the automatic entry of all necessary metadata (several fields will still require manual entry, especially local fields) but allows for more complete customized and accessible metadata about the file.

See http://www.adobe.com/products/xmp/index.html for more detailed information on the XMP specification and other related documents.

- *Will the metadata need to interact or be exchanged with other systems?*

This requirement reinforces the need for standardized ways of recording metadata so that it will meet the requirements of other systems. Mapping from an element in one scheme to an analogous element in another scheme will require that the meaning and structure of the data is shareable between the two schemes in order to ensure usability of the converted metadata. Metadata will also have to be stored in or assembled into a document format, such as XML, that promotes easy exchange of data. METS-compliant digital objects, for example, promote interoperability by virtue of their standardized, "packaged" format.

- *At what level of granularity will the metadata be recorded?*

Will metadata be collected at the collection level, the series level, the imaging project level, the item (digital object) level, or file level? Although the need for more precise description of digital resources exists so that they can be searched and identified, for many large-scale digitization projects this is not realistic. Most archival or special collections, for example, are neither organized around nor described at the individual item level and cannot be without significant investment of time and cost. Detailed description of records materials is often limited by the amount of information known about each item, which may require significant research into identification of subject matter of a photograph, for example, or even what generation of media format is selected for scanning. Metadata will likely be derived from and exist on a variety of levels, both logical and file, although not all levels will be relevant for all materials. Certain information required for preservation management of the files will be necessary at the individual file level. An element indicating level of aggregation (e.g., item, file, series, collection) at which metadata applies can be incorporated or the relational design of the database may reflect the hierarchical structure of the materials being described.

We recommend that standards, if they exist and apply, be followed for the use of data elements, data values, and data encoding. Attention should be paid to how data is entered into fields and whether controlled vocabularies have been used, in case transformation is necessary to normalize the data.

8.5.1 Relationships

Often basic relationships among multi-page or multi-part files are documented in a file naming scheme, where metadata is captured as much as possible in the surrounding file structure (names, directories, headers). However, we consider that simple, unique, meaningless names for file identifiers, coupled with more sophisticated metadata describing relationships across files stored in an external database, is the preferred way forward to link files together. This metadata might include file identifiers and metadata record identifiers and a codified or typed set of relationships that would help define the associations between digital files and between different representations of the same resource. (Relationships between the digital object and the analog source object or the place of the digital object in a larger collection hierarchy would be documented elsewhere in descriptive metadata). Possible relationship types include identification of principal or authoritative version (for master image file); derivation relationships indicating what files come from what files; whether the images were created in-house or come from outside sources; structural relationships (for multi-page or –part objects); sibling relationships (images of the same intellectual resource, but perhaps scanned from different source formats).

8.5.2 Permanent and Temporary Metadata

When planning for a digital imaging project, it may not be necessary to save all metadata created and used during the digitization phase of the project. For example, some tracking data may not be needed once all quality control and reshoot work has been completed. It may not be desirable, or necessary, to bring all metadata into a digital repository. An institution may decide not to explicitly record metadata that can easily be recalculated in the future from other information, such as image dimensions if resolution and pixel dimensions are known, or certain file format properties that might be derived directly from the file itself through an application such as JHOVE. Also, it may not be desirable or necessary to provide access to all metadata that is maintained within a system to all users. Most administrative and technical metadata will need to be accessible to administrative users to facilitate managing the digital assets, but does not need to be made available to general users searching the digital collections.

Chapter 9: Identifiers and File Naming

9.1 File Naming

A file-naming scheme should be established prior to capture. The development of a file naming system should take into account whether the identifier requires machine- or human-indexing (or both – in which case, the image may have multiple identifiers). File names can either be meaningful (such as the adoption of an existing identification scheme which correlates the digital file with the source material), or non-descriptive (such as a sequential numerical string). Meaningful file names contain metadata that is self-referencing; non-descriptive file names are associated with metadata stored elsewhere that serves to identify the file. In general, smaller-scale projects may design descriptive file names that facilitate browsing and retrieval; large-scale projects may use machine-generated names and rely on the database for sophisticated searching and retrieval of associated metadata.

A file naming system based on non-descriptive, non-mnemonic, unique identifiers usually requires a limited amount of metadata to be embedded within the file header, as well as an external database which would include descriptive, technical, and administrative metadata from the source object and the related digital files.

One advantage of a non-descriptive file naming convention is that it eliminates non-unique and changeable descriptive data and provides each file with a non-repeating and sustainable identifier in a form that is not content-dependent. This allows much greater flexibility for automated data processing and migration into future systems. Other benefits of a non-descriptive file naming convention include the ability to compensate for multiple object identifiers and the flexibility of an external database, which can accommodate structural metadata including parts and related objects, as well as avoiding any pitfalls associated with legacy file identifiers.

Recommended Characteristics of File Names

- Are unique – no other digital resource should duplicate or share the same identifier as another resource. In a meaningful file-naming scheme, names of related resources may be similar, but will often have different characters, prefixes, or suffixes appended to delineate certain characteristics of the file. An attempt to streamline multiple versions and/or copies should be made.
- Are consistently structured – file names should follow a consistent pattern and contain consistent information to aid in identification of the file as well as management of all digital resources in a similar manner. All files created in digitization projects should contain this same information in the same defined sequence.
- Are well-defined – a well-defined rationale for how/why files are named assists with standardization and consistency in naming and will ease in identification of files during the digitization process and long afterwards. An approach to file naming should be formalized for digitization projects and integrated into systems that manage digital resources.

- Are persistent – files should be named in a manner that has relevance over time and is not tied to any one process or system. Information represented in a file name should not refer to anything that might change over time. The concept of persistent identifiers is often linked to file names in an online environment that remain persistent and relevant across location changes or changes in protocols to access the file.
- Observant of any technical restrictions – file names should be compliant with any character restrictions (such as the use of special characters, spaces, or periods in the name, except in front of the file extension), as well as with any limitations on character length. Ideally, file names should not contain too many characters. Most current operating systems can handle long file names, although some applications will truncate file names in order to open the file, and certain types of networking protocols and file directory systems will shorten file names during transfer. Best practice is to limit character length to no more than 32 characters per file name.

General Guidelines for Creating File Names

- We recommend using a period followed by a three-character file extension at the end of all file names for identification of data format (for example, .tif, .jpg, .gif, .pdf, .wav, .mpg, etc.) A file format extension must always be present.
- Take into account the maximum number of items to be scanned and reflect that in the number of digits used (if following a numerical scheme).
- Use leading 0's to facilitate sorting in numerical order (if following a numerical scheme).
- Do not use an overly complex or lengthy naming scheme that is susceptible to human error during manual input.
- Use lowercase characters and file extensions.
- Record metadata embedded in file names (such as scan date, page number, etc.) in another location in addition to the file name. This provides a safety net for moving files across systems in the future, in the event that they must be renamed.
- In particular, sequencing information and major structural divisions of multi-part objects should be explicitly recorded in the structural metadata and not only embedded in filenames.
- Although it is not recommended to embed too much information into the file name, a certain amount of information can serve as minimal descriptive metadata for the file, as an economical alternative to the provision of richer data elsewhere.
- Alternatively, if meaning is judged to be temporal, it may be more practical to use a simple numbering system. An intellectually meaningful name will then have to be correlated with the digital resource in an external database.

9.2 Directory Structure

Regardless of file name, files will likely be organized in some kind of file directory system that will link to metadata stored elsewhere in a database. Master files might be stored separately from derivative files, or directories may have their own organization independent of the image files, such as folders arranged by date or collection identifier, or they may replicate the physical or logical organization of the originals being scanned.

The files themselves can also be organized solely by directory structure and folders rather than embedding meaning in the file name. This approach generally works well for multi-page items. Images are uniquely identified and aggregated at the level of the logical object (i.e., a book, a chapter, an issue, etc.), which requires that the folders or directories be named descriptively. The file names of the individual images themselves are unique only within each directory, but not across directories. For example, book 0001 contains image files 001.tif, 002.tif, 003.tif, etc. Book 0002 contains image files 001.tif, 002.tif, and 003.tif. The danger with this approach is that if individual images are separated from their parent directory, they will be indistinguishable from images in a different directory.

9.3 Versioning

For various reasons, a single scanned object may have multiple but differing versions associated with it (for example, the same image prepped for different output intents, versions with additional edits, layers, or alpha channels that are worth saving, versions scanned on different scanners, scanned from different original media, scanned at different times by different scanner operators, etc.). Ideally, the description and intent of different versions should be reflected in the metadata; but if the naming convention is consistent, distinguishing versions in the file name will allow for quick identification of a particular image. Like derivative files, this usually implies the application of a qualifier to part of the file name. The reason to use qualifiers rather than entirely new names is to keep all versions associated with a logical object under the same identifier. An approach to naming versions should be well thought out; adding 001, 002, etc. to the base file name to indicate different versions is an option; however, if 001 and 002 already denote page numbers, a different approach will be required.

9.4 Naming Derivative Files

The file naming system should also take into account the creation of derivative image files made from the master files. In general, derivative file names are inherited from the masters, usually with a qualifier added on to distinguish the role of the derivative from other files (i.e., “pr” for printing version, “t” for thumbnail, etc.) Derived files usually imply a change in image dimensions, image resolution, and/or file format from the master. Derivative file names do not have to be descriptive as long as they can be linked back to the master file.

For derivative files intended primarily for Web display, one consideration for naming is that images may need to be cited by users in order to retrieve other higher-quality versions. If so, the derivative file name should contain enough descriptive or numerical meaning to allow for easy retrieval of the original or other digital versions.

Chapter 10: Quality Management

Quality control (QC) and quality assurance (QA) are the processes used to ensure digitization and metadata creation are done properly. QC/QA plans and procedures should be initiated, documented and maintained throughout all phases of digital conversion. The plan should address all specifications and reporting requirements associated with each phase of the conversion project, including issues relating to the image files, the associated metadata, and the storage of both (file transfer, data integrity). Also, QC/QA plans should address accuracy requirements for and acceptable error rates for all aspects evaluated. For large digitization projects it may be appropriate to use a statistically valid sampling procedure to inspect files and metadata. In most situations QC/QA are done in a 2-step process- the scanning technician will do initial quality checks during production followed by a second check by another person.

10.1 Inspection of Digital Image Files

Inspection of image files involves two processes.

The first is a technical inspection of the file assuring correct imaging parameters were used when imaging, and that the file is valid. JHOVE is a software tool widely used by cultural heritage institutions to validate conformance to image technical specifications. The use of this tool is highly recommended as a part of an inspection program.

Information about JHOVE can be found here: http://jhove.openpreservation.org/

Image quality must then be visually inspected on a profiled graphics workstation by a trained technician, using the following procedure:

A visual review of thumbnails of all images should be done to assure completeness and consistency of the imaging. The initial review is followed by a detailed examination of a subset of the project. This visual evaluation of the images shall be conducted while viewing the images at a 1 to 1 pixel ratio or 100% magnification on the monitor.

We recommend, at a minimum, 10 images or 10 % of each batch of digital images, whichever quantity is larger, should be inspected for compliance with the digital imaging specifications and for defects in the following areas:

File Related

- Files open and display
- Proper format
  - TIFF, JPEG 2000
- Compression
  - Compressed if desired
  - Proper encoding (LZW, ZIP)
- Color mode
  - RGB
  - Grayscale
  - Bitonal
- Bit depth
  - 24-bits or 48-bits for RGB
  - 8-bits or 16-bits for grayscale
  - 1-bit for bitonal
- Color profile (missing or incorrect)
- Paths, channels, and layers (present if desired)

Original/Document Related

- Completeness
  - Compare source records with their digitized versions to verify that 100% of the source materials have been captured and accounted for, and
  - That the digitized records are in the same order as the original
- Correct dimensions
- Spatial resolution
  - Correct resolution
  - Correct units (inches or cm)
- Orientation
  - Document- portrait/vertical, landscape/horizontal
  - Image- horizontally or vertically flipped
- Proportions/Distortion
  - Distortion of the aspect ratio
  - Distortion of or within individual channels
- Image skew
- Cropping
  - Image completeness
  - Targets included
- Scale reference (if present, such as engineering scale or ruler)
- Missing pages or images

Metadata Related – see below for additional inspection requirements relating to metadata

- Named properly

- Data in header tags (complete and accurate)
- Descriptive metadata (complete and accurate)
- Technical metadata (complete and accurate)
- Administrative metadata (complete and accurate)

Image Quality Related

- Tone
  - Brightness
  - Contrast
  - Target assessment – aimpoints
  - Clipping – detail lost in high values (highlights) or dark values (shadows) – not applicable to 1-bit images
- Color
  - Accuracy
  - Target assessment – aimpoints
  - Clipping – detail lost in individual color channels
- Aimpoint variability
- Saturation
- Channel registration
  - Misregistration
  - Inconsistencies within individual channels
- Quantization errors
  - Banding
  - Posterization
- Noise
  - Overall
  - In individual channels
  - In areas that correspond to the high density areas of the original
  - In images produced using specific scanner or camera modes
- Artifacts
  - Defects
  - Dust
  - Newton's rings
  - Missing scan lines, discontinuities, or dropped-out pixels
- Detail
  - Loss of fine detail
  - Loss of texture
- Sharpness
  - Lack of sharpness
  - Over-sharpened
  - Inconsistent sharpness
- Flare
- Evenness of tonal values, of illumination, and vignetting or lens fall-off (with digital cameras)

This list has been provided as a starting point; it should not be considered comprehensive.

10.2 Quality Control of Metadata

Quality control of metadata should be integrated into the workflow of any digital imaging project. Because metadata is critical to the identification, discovery, management, access, preservation, and use of digital resources, it should be subject to quality control procedures similar to those used for verifying the quality of digital images. Since metadata is often created and modified at many points during an image's life cycle, metadata review should be an ongoing process that extends across all phases of an imaging project and beyond.

As with image quality control, a formal review process should also be designed for metadata. The same questions should be asked regarding who will review the metadata, the scope of the review, and how great a tolerance is allowed for errors (if any, as errors can have a deleterious effect on the proper discovery and retrieval of digital resources).

Practical approaches to metadata review may depend on how and where the metadata is stored, as well as the extent of metadata recorded. It is less likely that automated techniques will be as effective in assessing the accuracy, completeness, and utility of metadata *content* (depending on its complexity), which will require some level of manual analysis. Metadata quality assessment will likely require skilled human evaluation rather than machine evaluation. However, some aspects of managing metadata stored within a system can be monitored using automated system tools (for example, a digital asset management system might handle verification of relationships between different versions of an image, produce transaction logs of changes to data, produce derivative images and record information about the conversion process, run error detection routines, etc.). Tools such as checksums (for example, the MD5 Message-Digest Algorithm) can be used to assist in the verification of data that is transferred or archived.

Although there are no clearly defined metrics for evaluating metadata quality, the areas listed below can serve as a starting point for metadata review. Good practice is to review metadata at the time of image quality review. In general, we consider:

- *Adherence to standards set by institutional policy or by the requirements of the imaging project.*

Conformance to a recognized standard, such as Dublin Core for descriptive metadata and the NISO Data Dictionary – Technical Metadata for Digital Still Images for technical and production metadata, is recommended and will allow for better exchange of files and more straightforward interpretation of the data. Metadata stored in encoded schemes such as XML can be parsed and validated using automated tools. However, these tools do not verify accuracy of the content, only accurate syntax. We recommend the use of controlled vocabulary fields or authority files whenever possible to eliminate ambiguous terms, or the use of a locally created standardized terms list.

- *Procedures for accommodating images with incomplete metadata.*

Procedures for dealing with images with incomplete metadata should be in place. The minimal amount of metadata that is acceptable for managing images (such as a unique identifier, or a brief descriptive title or caption, etc.) should be determined. If there is no metadata associated with an image, does this preclude the image from being maintained over time?

- *Relevancy and accuracy of metadata.*

How are data input errors handled? Poor quality metadata means that a resource is essentially invisible and cannot be tracked or used. Check for correct grammar, spelling, and punctuation, especially for manually keyed data.

- *Consistency in the creation of metadata and in interpretation of metadata.*

Data should conform to the data constraints of header or database fields, which should be well defined. Values entered into fields should not be ambiguous. Limit the number of free text fields. Documentation such as a data dictionary can provide further clarification on acceptable field values.

- *Consistency and completeness in the level at which metadata is applied.*

Metadata is collected on many hierarchical levels (file, item, series, collection, etc.), across many versions (format, size, quality), and applies to different logical parts (item or document level, page level, etc.). Information may be mandatory at some levels and not at others. Data constants can be applied at higher levels and inherited down if they apply to all images in a set.

- *Evaluation of the usefulness of the metadata being collected.*

Is the information being recorded useful for resource discovery or management of image files over time? This is an ongoing process that should allow for new metadata to be collected as necessary.

- *Synchronization of metadata stored in more than one location.*

Procedures should be in place to make sure metadata is updated across more than one location. Information related to the image might be stored in the TIFF header, the digital asset management system, and other databases, for example.

- *Representation of different types of metadata.*

Has sufficient descriptive, technical, and administrative metadata been provided? All types must be present to ensure preservation of and access to a resource. All mandatory fields should be complete.

- *Mechanics of the metadata review process.*

A system to track the review process itself is helpful. This could be tracked using a database or a folder system that indicates status.

Specifically, we consider:

- *Verifying accuracy of file identifier.*

File names should consistently and uniquely identify both the digital resource and the metadata record (if it exists independently of the file). File identifiers will likely exist for the metadata record itself in addition to identifiers for the digitized resource, which may embed information such as page or piece number, date, project or institution identifier, among others. Information embedded in file identifiers for the resource should parallel metadata stored in a database record or header. Identifiers often serve as the link from the file to information stored in other databases and must be accurate to bring together distributed metadata about a resource. Verification of identifiers across metadata in disparate locations should be made.

- *Verifying accuracy and completeness of information in image header tags.*

The application Bridge in Adobe Photoshop CS can be used to display some of the default header fields and IPTC fields for quick review of data in the header. However, the tool does not allow for the creation or editing of header information. Special software is required for editing header tags.

- *Verifying the correct sequence and completeness of multi-page items.*

Pages should be in the correct order with no missing pages. If significant components of the resource are recorded in the metadata, such as chapter headings or other intellectual divisions of a resource, they should match up with the actual image files. For complex items such as folded pamphlets or multiple views of an item (a double page spread, each individual page, and a close-up section of a page, for example), a convention for describing these views should be followed and should match with the actual image files.

- *Adherence to agreed-upon conventions and terminology.*

Descriptions of components of multi-page pieces (i.e., is “front” and “back” or “recto” and “verso” used?) or descriptions of source material, for example, should follow a pre-defined, shared vocabulary.

10.3 Testing Results and Acceptance/Rejection

If more than 1% of the total number of images and associated metadata in a batch, based on the randomly selected sampling, are found to be defective for any of the reasons listed above, the entire batch should be re-inspected. Any specific errors found in the random sampling and any additional errors found in the re-inspection should be corrected. If less than 1% of the batch is found to be defective, then only the specific defective images and metadata that are found should be redone.

Chapter 11: Storage Recommendations

We recommend that master image files be stored on hard drive systems with a level of data redundancy, such as RAID (redundant array of independent disks) drives, rather than on optical media, such as CD-R or DVD. An additional set of images with metadata stored on an open standard tape format (such as

LTO) is recommended (CD-R or DVD as backup is a less desirable option), and a backup copy should be stored offsite. Regular backups of the images onto tape from the RAID drives are also recommended. A checksum should be generated and should be stored with the image files.

We do not recommend that CD-ROMs or DVDs be used as a long-term storage medium. However, if images are stored on these media, we recommend using high quality or "archival" quality media that has passed ISO 10995 certification. The term "archival" indicates the materials used to manufacture the CD or DVD (usually the dye layer where the data is recording, a protective gold layer to prevent pollutants from attacking the dye, or a physically durable top-coat to protect the surface of the disk) are reasonably stable and have good durability, but this will not guarantee the longevity of the media itself. All disks need to be stored and handled properly. We do not recommend using inexpensive or non-brand name CDs or DVDs, because generally they will be less stable, less durable, and more prone to recording problems.

All disks need to be stored and handled properly. Two (or more) copies should be made. One copy should not be handled, and should be stored offsite. Most importantly, a procedure for migration of the files off of the disks should be in place. In addition, all copies of the CDs or DVDs should be periodically checked using a metric such as a CRC (cyclic redundancy checksum) for data integrity. For large-scale projects or for projects that create very large image files, the limited capacity of CD storage will be problematic. DVDs may be considered for large projects, however, DVD formats are not as standardized as the lower-capacity CD formats, and compatibility and obsolescence is likely to be a problem.

11.1 Digital Repositories and the Long-Term Management of Files and Metadata

Digitization of archival records and creation of metadata represent a significant investment in terms of time and money. It is important to realize that the protection of these investments will require the active management of both the image files and the associated metadata. Storing files to CD or DVD and putting them on a shelf will not ensure the long-term viability of the digital images or the continuing access to them.

We recommend digital image files and associated metadata be stored and managed in an ISO 16363 compliant digital repository, see https://dictionary.archivists.org/entry/trustworthy-repositories-audit-and-certification.html.

Appendix A: Glossary

This glossary includes terms found in this document, and is intended to be a reference tool for using these *Guidelines*. It is not an exhaustive list of all terminology relating to still image digitization or digital content. For full definitions of all terms in this document glossary, more terms relating to digitization and digital content, additional examples for certain terms, and cross-references, please visit the comprehensive FADGI Glossary at http://www.digitizationguidelines.gov/glossary.php.

Access or Derivative file

Often called *service*, *access*, *delivery*, *viewing*, or *output* files, derivative files are by their nature secondary items, generally not considered to be permanent parts of an archival collection. To produce derivative files, organizations use the archival master file or the production master file as a data source and produce one or more derivatives, each optimized for a particular use. Typical uses (each of which may require a different optimization) include the provision of end-user access; high quality reproduction; or the creation of textual representations via OCR.

Accuracy

The degree to which the information correctly describes the object or process being measured. It can be thought of in terms of how close a reading or average of readings is to a true or target value. Accuracy is a different measure than precision.

Adobe RGB (1998)

Adobe RGB (1998) is a Red-Green-Blue color space developed to display on computer monitors most of the colors of CMYK color printers. The Adobe RGB (1998) color space is significantly larger than the sRGB color space, particularly in the cyan and green regions.

Aimpoint

A specific value assigned to a given metric to assess performance achievement.

Ambient light

Light existing in the environment that is not produced by the imaging system. Ambient light can be natural or artificial light. Ambient light is generally uncontrolled and can be highly variable, posing a possible risk to image quality. The level of ambient light should be minimized in relation to the level of light produced by the imaging system.

American National Standards Institute (ANSI)

The American National Standards Institute (ANSI) is a private nonprofit organization that administers and coordinates the United States voluntary standards and conformity assessment system.

Apochromatic lens

Lens designed to bring all colors into focus on the same plane. Film scanning lenses must be apochromatic and of a flat field design.

Application profile

Metadata set that consists of data elements drawn from different metadata schemas, which are combined, customized, and optimized for a particular local application or project.

Archival master file

File that represents the best copy produced by a digitizing organization, with *best* defined as meeting the objectives of a particular project or program. These objectives differ from one content category to another. In some cases, an archive may produce more than one archival master file. The terms used to name types of files vary within the digital library and digital archiving communities. In many cases, the best copies are called *preservation master files* rather than *archival master files*. In some cases, best-copy files are defined in qualitative terms, as part of an approach that requires all archival or preservation master files to meet the same specifications, without regard to objectives that vary by category. Archival master files represent digital content that the organization intends to maintain for the long term without loss of essential features. Master files of all types have permanent value and should be managed in an appropriate environment, e.g., one in which read and write executions are minimized and other preservation-oriented data management actions are applied. In contrast, derivative files are frequently accessed by end-users and are typically stored in systems that see repeated read and write executions.

Array

Any orderly arrangement of individual sensor elements. In digital imaging, there are primarily three array types; two dimensional or area arrays, one dimensional or linear arrays, and tri-linear arrays consisting of three consecutive linear arrays of red, green, and blue sensitive sensor elements.

Artifact (defect)

General term to describe a broad range of undesirable flaws or distortions in digital reproductions produced during capture or data processing. Some common forms of image artifacts include noise, chromatic aberration, blooming, interpolation, and imperfections created by compression, among others.

Aspect ratio

The relationship between the horizontal and vertical dimensions of an image. The horizontal dimension is normally listed first. For example, a 4-inch (vertical) by 6-inch (horizontal) print has an aspect ratio of 3:2.

Automatic document feeder (ADF)

An attachment that can be added to many flatbed scanners to allow scanning batches of loose sheets in an unattended manner, often referred to as an *ADF,* automatic document feed scanner, or sheetfed scanner.

Bayer color filter array

A specific two-dimensional mosaic pattern of repeating 2x2 RGB filtered sensors from which three fully populated red, green, and blue pixel arrays are mathematically reconstructed. A subset of color filter array.

Bitonal digital image

A single-bit image comprised of a pixel value of 0 or 1 (or, in some circumstances, as 0 and 255), corresponding to either black or white. This type of image is often used for typography (as in a FAX) and for line art graphs and pictorial works.

Bit depth

The number of bits used to represent each pixel in an image. The term can be confusing since it is sometimes used to represent bits per pixel and at other times, the total number of bits used multiplied by the number of total channels. For example, a typical color image using 8-bits per channel is often referred to as a 24-bit color image (8-bits x 3 channels). Color scanners and digital cameras typically produce 24-bit (8-bits x 3 channels) images or 36-bit (12 bits x 3 channels) capture, and high-end devices can produce 48-bit (16-bit x 3 channels) images. A grayscale scanner would generally be 1-bit for monochrome or 8-bit for grayscale (producing 256 shades of gray). Bit depth is also referred to as color depth.

Brightness

The attribute of the visual sensation that describes the perceived intensity of light. Brightness is among the three attributes that specify color. The other two attributes are hue and saturation.

Calibration

The comparison of instrument performance to a standard of higher accuracy. The standard is considered the reference and the more correct measure. Calibrations should be performed against a specified tolerance.

Checksum (Hash algorithm)

A hash algorithm is a function that converts a data string into a numeric string output of fixed length. The output string is generally much smaller than the original data. Hash algorithms are designed to be collision-resistant, meaning that there is a very low probability that the same string would be created for different data. Two of the most common hash algorithms are the MD5 (Message-Digest algorithm 5) and the SHA-1 (Secure Hash Algorithm). MD5 Message Digest checksums are commonly used to validate data integrity when digital files are transferred or stored.

Chromatic

In common terms, chromatic refers to light having the perceived quality of color, as opposed to achromatic. More specifically, chromatic has the quality of hue. All colors other than the neutral colors of gray, black and white are chromatic.

Chromatic aberration

An image defect caused when different wavelengths of light are focused at different distances from a lens. This results in varying degrees of sharp focus at the image sensor depending on the color or wavelength of light. Chromatic aberration is seen as "color fringing," and is most noticeable in an image at edges with high contrast.

Clipping

The abrupt truncation of a signal when the signal exceeds a system's ability to differentiate signal values above or below a particular level. In the case of images, the result is that there is no differentiation of light tones when the clipping is at the high end of signal amplitude, and no differentiation of dark tones when clipping occurs at the low end of signal amplitude.

CMYK

A subtractive color model used in printing that is based on cyan (C), magenta (M), yellow (Y) and black (K). These are typically referred to as process colors. Cyan absorbs the red component of white light, magenta absorbs green, and yellow absorbs blue. In theory, the mix of the three colors will produce black, but a black ink is used to increase the density of black in a print.

Color channel

A color channel stores the color information for one of the primary color components of a color model. For example, the RGB color model has three separate color channels; one for red, one for green and one for blue.

Color filter array

Digital image sensors used in scanners and digital cameras do not respond in a manner that differentiates color. The sensors respond to the intensity of light: the pixel that receives greater intensity produces a stronger signal. A color filter array (CFA) is a mosaic of color filters (generally red, green and blue) that overlays the pixels comprising the sensor. The color filters limit the intensity of light being recorded at the pixel to be associated with the wavelengths transmitted by that color. A demosaicing algorithm is able to take the information about the spectral characteristics of each color of a filter array, and the intensity of the signal at each pixel location to create a color encoded digital image.

Color management

The use of software, hardware and procedures to measure and control color in an imaging system, including capture and display devices.

Color management module (CMM)

Performs the calculations that transform color descriptions between color spaces using the source and destination profiles and the rendering intent.

Color misregistration

Color-to-color spatial dislocation of otherwise spatially coincident color features of an imaged object.

Color mode

A general description of the method of digital imaging based on color and bit depth. The three modes most often used in digital imaging are the following:

- Color: Digital images produced using a specified color model and color space (see definitions below) with combinations of light (ex. red, green, and blue light in an RGB color model) to represent the colors of the original object.
- Grayscale: Digital images produced using a range of grays between white and black.
- Bitonal: Digital images produced using only two colors, black and white.

Color model

A color model is a way of specifying or describing a color numerically; common examples include RGB and CMYK. For example, in the 24-bit-deep RGB color model, the intensity of each of the red, green and blue components of the model (8-bits for each channel) are represented on a scale from 0 to 255. The lowest intensity of any color represented by 0 and 255 representing the maximum intensity. There are two main categories of color models, additive and subtractive. Additive color models (such as RGB) are based on transmitted light while subtractive color models (such as CMYK) are based on reflected light.

Color Rendering Index (CRI)

A measure of how close the spectral distribution is to the reference (the sun). A CRI above 90 is generally accepted as appropriate for most cultural heritage imaging. All light sources have variations in their spectral distribution. Light sources that have serious deficiencies in their spectral distribution are unsuitable for use in a cultural heritage imaging environment.

Color SFR difference

The differential spread of light between color channels.

Color space

A specific organization of colors that supports reproducible representations of color in combination with color profiling supported by various devices. A color space can be a helpful conceptual tool for describing or understanding the color capabilities of a particular device or digital file. Examples of color spaces include Adobe RGB (1998), sRGB, ECIRGB_v2, and ProPhoto RGB.

Color temperature

Color temperature is a simplified characterization of the visible spectral properties of a light source. It refers to the absolute temperature (in degrees Kelvin, i.e., Celsius-sized degree units above absolute zero) to which one would have to heat a theoretical "black body" source to produce light in a continuous spectrum and of a certain color. The more a light source deviates from a theoretical "black body" the poorer the model works to describe the visible characteristics of the light source, e.g., fluorescent lights that emit a discontinuous spectrum. The higher the color temperature, the more "cool" the light source is considered to be.

Colorimetry

The science of measuring color and color appearance.

Compression (data)

The process of encoding data in a manner that reduces the amount of information required than required for the uncompressed data. Compression techniques can be categorized into two major categories: lossless and lossy.

Compression, lossless

Data compressed using a lossless compression technique will allow the decompressed data to be exactly the same as the original data before compression, bit for bit. The compression of data is achieved by coding redundant data in a more efficient manner than in the uncompressed format.

Compression, lossy

Data compressed using a lossy compression technique results in the loss of information. The decompressed data will not be identical to the original uncompressed data.

Contrast

Any difference in luminance level between regions of interest

Copy negatives and transparencies

Pertains to the copying of pictorial works, maps, illustrative plates in books, posters, etc., i.e., items viewed by reflected light.

Cropping

Cropping is an image-editing/processing technique whereby an unwanted portion or portions of a digital image are removed. Cropping is usually performed to remove some portion of one or more outside edges of the image. Cropping may be performed in different manners to the same image depending on its intended use.

Density

Density can refer to either transmission density or reflection density. Transmission density refers to the opacity of the object and is measure of the percentage of light transmitted through the object when compared with the amount of light striking the object.

Data logger

Electronic device used to automatically monitor and record environmental parameters over time (also referred to as environmental data logger). This allows conditions to be measured, documented, analyzed, and validated, and to maintain consistent environmental conditions in an imaging work space.

Deskew

An image processing method to correct the skew exhibited in a digital image. Automated deskew functions are often features of scanning or OCR software applications.

Digital image conformance evaluation

Repeatable and reliable methods of validating the consistency and accuracy of imaging “goodness” as defined in this document for the various types of materials covered in this document.

Note: Previous versions of these guidelines referred to this as the definition for the acronym “DICE”, which was the term used when these *Guidelines* were intended only for the Library of Congress and other U.S. federal agency members of FADGI. These guidelines have since evolved from a federal government document to a community-focused document, and this acronym is no longer appropriate. OpenDICE is the name of a software application developed through funding by the Library of Congress.

Digital image

The visual manifestation of a digitally encoded representation of the visual characteristics of an object. The term is also used as shorthand for a digital image file.

Digital imaging

The process of creating digital images. The term may also be used more generally to include digital image processing.

Digitization

The process of recording an analog signal in a digital form. In relation to content of this document, it describes the process of translating analog signal data emanating from an object (light) into a digitally encoded format.

Distortion

The alteration of the original shape (or other characteristic) of an object, image, or other form of information or representation, usually unwanted.

Distortion, geometric

Distortion in which the true geometry of an object is not properly represented in the digital image, e.g., barrel (sides of a square bulge out) or pincushion (sides of a square curve inward). Some factors that can cause geometric distortion include: system optics, sensor defects, or mis-position of the image plane relative to the plane of the object being digitized.

Dots per inch (DPI)

DPI stands for dots per inch, and was originally used specifically as a term in printing, providing a measure of how many dots of ink are placed on a print in distance of one inch. The terms DPI and PPI (pixels per inch) are used somewhat interchangeably today, with scanner manufacturers often providing specifications on resolution in DPI.

Dynamic range

Dynamic range is the difference of the minimum and maximum density values an imaging system can capture (D max minus D min). The dynamic range is calculated for both capture systems and source material.

Encoding

The transformation of a signal or data into a code by means of a programmed algorithm. The code may serve any of a number of purposes such as transforming analog information into digital form, compressing information for transmission or storage, encrypting or adding redundancies to the input code, or translating from one code to another.

ECIRGB_v2

A color space developed by the European Color Initiative and recommended in the *Metamorfoze Preservation Imaging Guidelines*.

Essential features

Curators and end users perceive digital content items as having a bundle of features, some of which invest the content with meaning or artistic impact, and these are termed *significant* or *essential*.

EXIF

Exchangeable image file format (EXIF) describes a metadata set to accompany TIFF, JPEG, and RIFF WAV formatted image files. The EXIF data structure is based on the TIFF tags and there is significant overlap between TIFF and EXIF metadata. Also specified is the relational information indicating the relation between image files and audio files.

Exposure

In digital imaging, exposure is the amount of light received by the image sensor. Exposure is determined by the intensity of light received by the sensor (number of photons), and the duration the sensor is exposed to the light; commonly referred to as shutter speed.

Extensible Metadata Platform (XMP)

A file format neutral specification (and proposed standard) developed by Adobe for embedding comprehensive metadata that is based on the RDF (Resource Description Framework) data model. With a basis on RDF, XMP inherently possesses many desirable characteristics for the representation and management of embedded metadata. Key characteristics include XML-based syntax and extensibility.

File format

Set of structural conventions that define a wrapper, formatted data, and embedded metadata, and that can be followed to represent images, audiovisual waveforms, texts, etc., in a digital object. The wrapper component on its own is often colloquially called a *file format*. The formatted data may consist of one or more encoded binary bitstreams for such entities as images or waveforms, and/or textually-encoded data, often marked up with XML or HTML, for texts. The embedded metadata may be skeletal or extensive.

Flare

A skirty or wide spreading of light. In photography and imaging, the term "lens flare" is frequently encountered and refers to generally unwanted light scattered by internal reflections and lack of homogeneity in the lens.

Flat fielding

Process that corrects for irregularities in pixel values caused by variations in pixel sensitivity in the camera sensor, dust or damage on a lens, uneven lighting, or distortions in the optical path to produce an image of uniform brightness. Flat fielding software can reduce non-uniformity in images. Lenses with a flat field design are best suited for cultural heritage imaging.

Gain (image)

In practical discussions of digital cameras and scanning devices, gain is described as a means of increasing the ISO of the device and apparent sensitivity to light. In more technical terms, gain in a digital imaging device represents the relationship between the number of electrons acquired on an image sensor and the analog-to-digital units (ADUs) that are generated, representing the image signal. Increasing the gain amplifies the signal by increasing the ratio of ADUs to electrons acquired on the sensor. The result is that increasing gain increases the apparent brightness of an image at a given exposure.

Gamut

The range of colors that can be generated by a specific output device (such as a monitor or printer), or can be interpreted by a color model. Often referred to as *color gamut*.

Gamma

This term has slightly different meanings in conventional photography and in digital imaging; this definition pertains to the latter. The human eye has a nonlinear response curve (it is more sensitive to variations in low light than to equal variation in bright light). In order to present viewers with images that look natural or correct, nonlinear representations are employed. Output devices like display monitors and printers are characterized in terms of their gamma (this can often be adjusted in a calibration step), and professional image-makers process their images (gamma correction) to cater to the output devices they intend to serve and/or to compensate for the inherent tone-reproduction performance of the capture device. Gamma is defined by power-law expressions and it is thus a parametric indicator of the level of non-linear light intensity behavior associated with an imaging device. A gamma = 1.0 is generally considered to be linear behavior.

Gamma correction

Gamma and gamma correction have to do with bridging the difference between linear representations of the intensities of light and the nonlinear response of the human eye, which is more sensitive to variations in low light than to equal variation in bright light. Gamma correction is an image processing operation that compensates for the inherent tone-reproduction behaviors of a capture device or to prepare an image for output to a monitor or printer, which may also be calibrated in non-linear terms.

GIF

The Graphics Interchange Format (GIF) is an 8-bit-per-pixel bitmap image format. The format produces images that are small and efficient through the use of a limited 256 color palette and of the Lempel-Ziv-Welch (LZW) lossless data compression scheme. GIF is widely used for graphics with areas of solid color such as maps, illustrations, logos and simple animations. The color limitations make it unsuitable for reproducing color photographs.

Grayscale

An image type lacking any chromatic data, consisting of shades of gray ranging from white to black. Most commonly seen as having 8-bits per pixel, allowing for 256 shades or levels of intensity.

H and D curve

The tone scale of a photographic negative is non-linear, with a relatively linear mid-section and lower contrast at both the high and low density parts of the film image. If measured and graphed, the values would look somewhat like an “S.” This is known as the “H and D curve”. Alternate spellings include H&D Curve, HD Curve, and H-D Curve.

Handprint character recognition (HCR)

A process that converts handwriting or lettering into machine generated characters. It is related to OCR (see below), which converts dots or pixels representing machine generated characters in a raster image to be converted into digitally coded text. The term handwritten text recognition (HTR) may be used synonymously with HCR.

High dynamic range (HDR) imaging

In photography and computer graphics, high dynamic range (HDR) imaging is a set of techniques that allow a greater dynamic range of exposures or values (i.e., a wide range of values between light and dark areas) than normal digital imaging techniques. The intention is to accurately represent the wide range of intensity levels found in such examples as exterior scenes that include light-colored items struck by direct sunlight and areas of deep shadow.

Hue

The attribute of color described by words such as red, blue and yellow. Hue, along with saturation and brightness are the three attributes that specify a color.

Illuminance

The total amount of light illuminating a point on a surface from all directions above the surface. Illuminance is equivalent to irradiance weighted with the tristimulus response curve of the human eye.

Image processing (digital)

The manipulation of digitally encoded image data. Two of the most common categories of image processing include image data compression and image enhancement. Typical processes include resizing, cropping, sharpening, rotating, and adjusting color or contrast.

International Color Consortium (ICC)

Established in 1993 to create, promote and encourage the standardization and evolution of an open, vendor-neutral, cross-platform color management system architecture. The resulting ICC specification (ISO 15076-1:2005) provides a cross-platform format to translate color data between devices in order to ensure color fidelity, and is specified in many international standards.

International Organization for Standardization (ISO)

The International Organization for Standardization (ISO) is the world’s largest standards organization. Since its formation in 1947, it has published more than 17,000 international standards in response to global needs. ISO standards are developed by 200 technical committees which include representatives from the industrial, technical and business sectors, with input from representatives of government agencies, consumer organizations, academia and testing laboratories.

IPTC Metadata

Embedded metadata used for image management. IPTC metadata is primarily composed of descriptive, administrative, and rights metadata, as opposed to the technical nature of EXIF. IPTC metadata was developed and is controlled by the International Press Telecommunications Panel.

ISO (film speed)

Used colloquially in the context of film photography, *ISO* followed by a number (e.g., 400) represented the sensitivity of a given film emulsion to light, often referred to as "film speed." Higher ISO numbers indicated a greater sensitivity to light. The emulsion speed sensitivity was determined by the standards of the International Organization for Standardization (ISO), which is how the term ISO came to be used in this context. In digital cameras and scanners, the image sensor has a fixed sensitivity or response to light, but the colloquial *ISO* is still used in a similar manner as with film. When changing the ISO on a digital imaging device, the gain is changed rather than the sensitivity of the image sensor. Increasing the gain increases the signal amplification from the sensor making it appear to be more sensitive. Increasing ISO on a digital camera or scanner increases the noise relative to the signal, decreasing the signal-to-noise ratio (SNR).

JHOVE

An open source application created by JSTOR and the Harvard University Library to perform format-specific identification, validation, and characterization of digital objects.

JPEG

The Joint Photographic Experts Group (JPEG) standard specifies the most common compression method applied to black & white and color images. JPEG compressed images can be viewed in any Internet browser and in hundreds of software applications available for all operating systems. JPEG generally provides a 10:1 compression ratio with minimum visual degradation, but the actual degree of compression can be adjusted, allowing the user to balance image quality and file size images created for the Internet. JPEG/EXIF is the most common image format used by digital cameras and other photographic image capture devices.

JPEG 2000 (JP2)

The Joint Photographic Experts Group developed JPEG 2000 as an open imaging compression and file format standard (ISO/IEC 15444-1:2000) with the intention of superseding their original JPEG standard. JPEG 2000 is a wavelet-based image compression method that provides much better image quality at smaller file sizes than the original JPEG method. The JPEG 2000 file format also offers significant improvements over earlier formats by supporting both lossless and lossy image compression within the same physical file. A full range of metadata may also be bundled within the file.

Line art

An image that consists of distinct straight and curved lines placed against a (usually plain) background, without gradations in shade or hue to represent two-dimensional or three-dimensional objects.

Lookup table (LUT)

A cross-referenced table that links an output value to every possible input value, which enables programs to make calculations very quickly. This is beneficial for evaluating and correcting color spaces.

Luminance

Luminance is the physical measure of brightness. The standard unit of luminance is candela per square meter (cd/m2).

LZW

LZW (Lempel-Ziv-Welch) Image Compression Encoding. A lossless compression algorithm for digital data of many kinds. LZW is based on a translation table that maps strings of input characters into codes.

Megapixel

A megapixel is one million pixels, and is commonly abbreviated "MP." The megapixel count of a camera sensor is one of the most common characteristics used in describing and comparing digital cameras.

Metadata

Information about an analog or digital object, a component of an object, or a coherent collection of objects. Metadata describing digital content is often structured (e.g., with tagging or markup) and it may be embedded within a single file, incorporated within the "packaging" that is associated with a group of files, placed in a related external file, or in a system external to the digital file (e.g., a database) to which the digital file or files are linked via a unique key or association.

Metadata, administrative

Metadata used for the management of digital content, such as information about rights and permissions as well as other facts about a given digital object.

Metadata, descriptive

Descriptive metadata provides information about the intellectual or artistic content of an object and may also contain data describing the physical attributes of the object. Descriptive metadata supports specific user tasks, such as discovery and identification of content.

Metadata, embedded

Embedded metadata is a component of a digital file that exists alongside the content (usually binary data) within the file, making the digital file self-describing.

Metadata, preservation

Term strongly associated with the Preservation Metadata for Digital Materials (PREMIS) working group. The group defined a core preservation metadata set, supported by a data dictionary, and identified strategies for encoding, storing, and managing this metadata. Many data elements that are important for preservation are found in other categories, especially those classified as administrative.

Metadata, structural

In digital library community usage, structural metadata describes the intellectual or physical elements of a digital object. For a file that represents a single page as a compound document, the structural metadata may include information on page layout. In a multi-file digital object (e.g., a scanned book with many page images), structural metadata describes the object's components and their relationships: pages, chapters, tables of contents, index, etc. Such metadata can support sophisticated search and retrieval actions as well as the navigation and presentation of digital objects.

Metadata, technical

Generic term for technical information about the digital files and multifile objects, as further defined by three terms for important aspects of technical information: (1) file-characteristics metadata for technical information about the formatted digital file in hand; (2) source metadata for technical information about the source item, whether analog or digital; and (3) process metadata for information about the technical processes used to convert the source item into the digital file that is described in (1).

Microfilm

The generic term *microform* covers reels of microfilm, sheet-form microfiche, aperture cards, and other types. Library and archive microfilming has generally been carried out by institutional *preservation programs* and the resulting films are generally called *preservation microfilms*. Practices for preservation microfilm vary by category of source content. Preservation microfilms can be seen as examples of virtual replicas, although specialists in the field do not use that term. By extension, the sets of digital images that reproduce microfilm content can also be seen as virtual replicas of the original items.

Midtone

Color in the middle of the tonal spectrum, neither dark nor light.

Modulation Transfer Function (MTF)

The sharpness of an imaging system can be characterized by its Modulation Transfer Function (MTF), which is generally equivalent to the Spatial Frequency Response (SFR). MTF is a measure of the ability of an imaging system to transfer levels of detail from object to image.

Note: SFR is a surrogate metric to MTF. There are some very minor differences between SFR and MTF. In the purest sense SFR may not give the same results due to assumptions about linearity and the response at the zero frequency. For simplicity these guidelines use SFR as the evaluation metric as SFR is much easier to calculate for field use.

Moiré pattern

A repeating low frequency geometric pattern induced by the interaction of two out-of-phase geometries of higher frequency. Moiré often occurs upon display of digitized halftone patterns caused by the out-of-phase interaction of the halftone pattern and sensor geometries.

Monochromatic

Light characterized by having a single wavelength. In more general usage, light or an image composed of a single hue.

National Information Standards Organization (NISO)

Founded in 1939, the National Information Standards Organization (NISO) is a non-profit association accredited by ANSI with the mission to identify, develop, maintain, and publish technical standards to manage and provide access to trusted information. Its nearly eighty voting members represent a variety of groups involved in the organization and distribution of information, including libraries, the information technology and publishing industries, and the vendor community. NISO maintains the Z39 series of standards.

Newton's rings

An interference pattern that appears as a series of concentric, alternating light and dark rings of colored light (when imaged in a color mode). This type of interference is caused when smooth transparent surfaces come into contact with small gaps of air between the surfaces. The light waves reflected from the top and bottom surfaces of the air film formed between the surfaces causing light rays to constructively or destructively interfere with each other. The areas where there is constructive interference will appear as light bands and the areas where there is destructive interference will appear as dark bands.

Noise

Data that obscures or corrupts *signal*, as that term is used in the expression signal-to-noise ratio. Although noise is generally *unwanted* and signal is *wanted*, there are exceptions. While noise is often thought of as a random phenomenon, it may be either random or systematic (patterned).

Nyquist frequency

The highest possible frequency that can be coded at a given sampling rate in order to be able to fully reconstruct the signal. According to the Nyquist Principle, a sampling rate must be at least twice the maximum bandwidth of the signal in order to allow the signal to be completely represented. In a camera sensor the Nyquist Frequency is equal to 0.5 cycles per pixel. The half sampling (Nyquist) frequency is half of 400 ppi, or 200 cycles/inch.

Nyquist principle

Nyquist principle states that the sampling rate must be at least twice the maximum bandwidth of the analog signal in order to allow the signal to be completely represented.

Open Archival Information System (OAIS)

A high-level model that describes the components and processes necessary for a digital archives, including six distinct functional areas: ingest, archival storage, data management, administration, preservation planning, and access.

Optical Character Recognition (OCR)

Optical Character Recognition (OCR) is a technology that allows dots or pixels representing machine generated characters in a raster image to be converted into digitally coded text. In addition to recognizing and coding text, OCR programs attempt to recognize and code the structural elements of a document page, such as columns and non-text graphical elements. OCR is generally part of a workflow that begins with scanning documents. Scanned images may be further processed or "cleaned" prior to OCR to improve accuracy of the recognition process. Modern OCR applications are capable of producing multiple output formats such as American Standard Code for Information Exchange (ASCII), Rich Text Format (RTF), Microsoft Word, Unicode Transformation Format—8-bit (UTF-8), UTF-16, or PDF. While some hardware applications for OCR exist, the vast majority of OCR is performed by software applications.

Opto-Electronic Conversion Function (OECF)

The average large area digital response of an electronic imaging device to light stimuli.

Pixel

An abbreviation of *picture element*, this term may refer to a component of either a digital image or a digital sensor. In the case of a digital image, the pixel is the smallest discrete unit of information in the image's structure. Images based in raster data can be thought of as a grid in which each cell is called a pixel. The amount of data recorded for each pixel can vary, and is expressed as bit depth or bits per pixel, often also as *per channel* in order to indicate the allocation of bits to different color channels. In the case of the sensor in a scanner or digital camera, a pixel is the smallest photosensitive component or cell providing a response to light (or photons). The photons collected at each pixel liberate electrons, which register as an electrical charge. The strength of the charge or signal is proportional to the number of photons collected at the pixel location. A primary measure used in describing a digital imaging device is the number of pixels the sensor comprises, normally expressed as megapixels (MP) or millions of pixels.

Pixels per inch (PPI)

PPI stands for pixels per inch, commonly used in describing the resolution capabilities of an imaging device such as a scanner or the resolution of a digital image. The terms DPI (dots per inch) and PPI are used somewhat interchangeably today.

Portable Document Format (PDF)

Adobe's Portable Document Format (PDF) is a document encoding system that maintains the original content, structure and appearance of a document across many computer platforms and communications networks. Adobe has created a near universal document format that is device and resolution independent. A free and widely available PDF viewer allows users to open, view, navigate, and usually print an electronic document. As of July 1, 2008 PDF has been recognized as international standard - ISO 32000-1:2008.

Posterization

An effect produced by reducing the number of tones (colors) in an image so that there is a noticeable distinction between one tone and another instead of a gradual shift.

Precision

The characteristic of measurement that relates to the consistency between multiple measurements of an identical item or process under uniform conditions. As opposed to accuracy, precision does not indicate how close a measurement is to a true value.

Printed halftone

Most photographs, paintings, or similar pictorial works reproduced in books, magazines and newspapers are printed as *halftones*. In a halftone, the continuous tones of the picture being reproduced are broken into a series of equally spaced dots of varying size, printed with only one color of ink. The outcome exploits an optical illusion: the tiny halftone dots are blended into smooth tones by the human eye.

Production master file

Files produced by processing the content in one or more archival master files, resulting in a new file or files with levels of quality that rival those of the archival master. The first type of processing consists of the assembly of a set of segments into a unified reproduction of an item. The second process that may be applied consists of aesthetic or other technical corrections to the original file.

Profile

Profiles are sets of numbers, either a matrix or look-up table (LUT), that describe a color space (the continuous spectrum of colors within the gamut, or outer limits, of the colors available to a device) by relating color descriptions specific to that color space to a profile connection space (PCS).

Profile Connection Space (PCS)

One of two device-independent measuring systems for describing color based on human vision, and is usually determined automatically by the source profile. Typically, end users have little direct interaction with the PCS.

ProPhoto RGB

ProPhoto RGB is a large gamut color space developed by Kodak primarily for photographic applications. The space encompasses 90% of the CIE L*a*b* color space - compared to Adobe RGB 1998's coverage of about 50%. ProPhoto RGB is also known as ROMM RGB for Reference Output Medium Metric RGB.

Quality Assurance (QA)

Quality Assurance (QA) is often equated with Quality Control (QC), but where QC activities are concentrated on detecting defects, QA is proactive and concerned with preventing defects by ensuring that the required levels of quality are achieved for a product or service. A QA program is heavily dependent on data from QC data to search for patterns and trends. QA activities also include controlled experiments, design reviews, and system tests. QA programs can influence quality through creating Quality Assurance Plans, quality-related policies, or creating and conducting trainings.

Quality Control (QC)

Quality control includes activities that examine products through observation or testing to determine if they meet their specifications. The purpose of this activity is to detect defects in products or processes where defects are defined as deviating from predetermined requirements.

Quality management

All activities of the overall management function that determine the quality policy, objectives and responsibilities, and implement them by means such as quality planning, quality control, quality assurance, and quality improvement within the quality system. (ISO 9000:2000)

Quantization

A lossy compression technique that involves compressing a range of values to a single quantum value, usually to reduce file size. This may result in errors or flaws in an image, such as posterization, caused by reducing the data available in an image file to represent aspects such as colors.

Raster data

Data in which a grid or raster of picture elements (pixels) has been mapped to represent a visual subject, e.g., the page of a book or a photograph. The term is derived from the Latin word for rake, suggesting the way in which that tool can be used to inscribe a grid pattern. The term *raster data* is often contrasted with vector data, in which geometrical points, lines, curves, and shapes are based upon mathematical equations, thus creating an image without specific mapping of data to pixels.

Raster image

Image based in raster data.

Redundant array of independent disks (RAID)

Storage technology that combines multiple independent physical disk drive components into one or more units to increase storage capacity and provide data redundancy.

Reference target

A chart of test patterns with known traceable values used to evaluate the performance of an imaging system.

Reflection, specular

Specular reflection is the type of reflection observed when light is reflected off a shiny, glossy or mirror-like surface, where light from a single incoming direction is reflected into a single outgoing direction. Stated in more standard terminology, the angle of incidence of the light ray is equal to the angle of reflection. Specular reflection may occur across the entire surface of an object or only a small portion of the surface.

Reflective object

An object that is intended to be, or is generally, viewed or used in a manner in which some or all of the light that strikes its surface is reflected. Most reflective objects are largely opaque, but may be translucent. For example, thin printed paper transmits a significant portion of the light striking it, but it is intended to be used in a reflective manner to properly read the text and interpret any graphics.

Reflective scanning

Digital imaging of an object where light is reflected from the object, generally a reflective object such as a map or printed page of text.

Rendering intent

Method or set of instructions for mapping or translating color values from one color space to another, generally when converting from a color space with a larger gamut to one with a smaller gamut. ICC defines four rendering intents (absolute colorimetric, relative colorimetric, perceptual and saturation).

Reproduction Scale

A reference scale usually part of an imaging target that contains a series of markings of known physical dimensions (inches or cm) that provides information of the size of the original subject.

Resolution

An imaging system's ability to resolve finely spaced detail. The level of spatial detail that can resolved in an image. The maximum spatial frequency of any utility for an imaging system (limiting resolution).

RGB

An additive color model based on the three primary colors of red (R), blue (B) and green (G).

Region of interest (ROI)

Any contiguous area portion of an image selected for processing, measurement, or interrogation.

Sampling frequency (signal)

The frequency that a signal is sampled along an axis.

Sampling rate (image)

The spatial frequency of the digital sampling. The reciprocal of the center-to-center distance between adjacent pixels.

Saturation

The attribute of color that expresses the degree of departure from a gray of the same lightness. When a color has no saturation, it is a shade of gray. Saturation describes the purity of a color, and along with hue and brightness is among the three attributes that specify a color.

Sheetfed scanner

A sheetfed scanner (also referred to as an *automatic document scanner* or ADF scanner) is a digital imaging system specifically designed for scanning loose sheets of paper, widely used by businesses to scan office documents and less frequently used by archives and libraries to scan books that have been disbound or other robust unbound documents.

Sensitivity

The reciprocal of the amount of light necessary to achieve a desired output response.

Sensor

Device that converts optical image into an electronic signal. Sensors detect and convey information used to create digital images, video, audio, and more. In digital imaging, the sensor allows the camera to convert photons (light) into electrical signals and data that can be interpreted by the capture device to create a digital representation of an object.

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.

Sharpness

The visually perceived quality of being crisp or of containing detail.

Signal-to-noise ratio

Abbreviated as SNR, it is a measure of the relative power of a desired or ideal signal to the power of an undesired signal or noise. SNR is typically measured in decibels.

Skew

The angle of deviation in a digital image from the paper edge, text lines or other visual reference elements. Skew is expressed numerically as the tangent of the deviation angle in degrees, either clockwise or counterclockwise. It applies to the angle of two-dimensional image orientation.

Spatial frequency

The reciprocal of the distance between any two cyclical spatial features.

Spatial Frequency Response (SFR)

Spatial Frequency Response (SFR) describes an imaging system's ability to maintain the relative contrast of input stimuli.

Note: SFR is a surrogate metric to MTF. There are some very minor differences between SFR and MTF. In the purest sense SFR may not give the same results due to assumptions about linearity and the response at the zero frequency. For simplicity these guidelines use SFR as the evaluation metric as SFR is much easier to calculate for field use.

sRGB

Standard RGB color space created by HP and Microsoft for use on monitors, printers, and the Internet. sRGB uses the ITU-R BT.709-5 primaries that are also used in studio monitors and HDTV, and a transfer function (gamma correction) typical of CRTs, all of which permits sRGB to be directly displayed on typical monitors. The sRGB gamma is not represented by a single numerical value. The overall gamma is approximately 2.2, consisting of a linear (gamma 1.0) section near black, and a non-linear section elsewhere involving a 2.4 exponent and a gamma changing from 1.0 through about 2.3.

Stitching

An image processing method combining multiple overlapping images to create a single image. Stitching can be used in scanning where a single scan of a large object is not able to produce sufficiently high resolution. Accurate digital alignment to create a visually seamless and uniform image from the individual component images is technically complex and challenging. Individual images comprising the stitched image are sometimes referred to as tiles.

TIFF

TIFF is a file format for storing and exchanging bitonal, grayscale, and color images. The term is now used without reference to the original source phrase: *Tag* or *Tagged Image File Format*. Developed by Aldus as a universal format for desktop scanners in the 1980s, TIFF came under Adobe's control when Adobe acquired Aldus. TIFF combines raster image data with a flexible tagged field structure for metadata.

TIFF header

The TIFF image format contains a flexible, extendable metadata structure based on a header that contains numerically tagged data fields. The *baseline tags* are listed and described in Part 1 (Baseline TIFF) of the TIFF 6.0 specification, where they are described as *Required Fields*. These 36 tags cover mainly technical metadata that any TIFF-specification compliant application must be able to read.

Thumbnail image

A small, low resolution file normally used as a preview of an image. A thumbnail image is often linked to a higher resolution version of the same image.

Tolerance

Allowable deviation from a specified value.

Transmissive object

An object that is intended to be, or is generally, viewed or used in a manner that allows light to pass through from one side of the object to the other. The viewing or use of the object is by way of the transmitted light. Examples of transmissive objects include photographic slides and negatives.

Transmissive scanning

Digital imaging of an object where light is transmitted through the object, generally a transmissive object such as a photographic slide or negative.

Tri-linear array

Three consecutive linear arrays of red, green, and blue sensitive sensor elements.

Use case

Use cases are often employed in information technology systems design and engineering. They describe the desired response of a system when it receives external requests. The technique is used to develop the behavioral requirements for a system by describing numerous functional scenarios. Each use case characterizes the interaction between an *actor* (which may be a human user, another system, or a hardware device that initiates an action) and the *system*. Use cases typically represent the function as a sequence of simple steps. Each use case is a complete series of events, as seen from the actor's point of view.

Vacuum table

A flat printing base with a series of small, finely spaced holes in its bed attached to a vacuum system. Works, such as photographic prints or maps, are placed on the table to make them lie flat. Vacuum tables used for this purpose often allow the user to adjust the level of vacuum to accommodate the object being scanned. Conservation practices often prohibit or restrict the use of vacuum tables in order to reduce the risk of accidental damage.

Viewing booth

An enclosed or semi-enclosed area with controlled lighting that is used as a consistent and controlled environment for evaluating visual objects, such as original prints and paintings as well as reproduction prints, and to compare originals with reproductions. Viewing booths are generally illuminated using known, standardized lighting such as D50 or D65 lighting.

Vignetting

A darkening or reduction in saturation towards the outer edges of an image compared to the center.

Visible spectrum

The band of electromagnetic radiation that human eyes can detect. This ranges from wavelengths of approximately 400 to approximately 700 nanometers (nm). Normal human vision responds slightly beyond this range to both shorter and longer wavelength radiation, but with very little sensitivity. Maximum sensitivity of the human vision in bright-light conditions is approximately 555 nm, corresponding to the perception of green. Visual sensitivity to wavelengths is dependent on luminance levels or levels of brightness, and is described as scotopic (dark-adapted) and photopic (light-adapted) sensitivities. A less common term is mesopic sensitivity, falling between dark and light-adapted sensitivity. The term "light" is equivalent in meaning to "visible spectrum." The section of the band of electromagnetic radiation with a wavelength shorter than that of visible light is termed ultraviolet and the section with wavelengths longer than that of visible light is termed infrared.

White balance

The equivalence of large area color channel output responses to a range of spectrally neutral input stimuli.

White point

A radiometric reference point used to calibrate or define the maximum luminance value of interest in a scene or object.

XMP sidecar file

XMP metadata may be extracted from an image file and stored in a separate, but related file called a *sidecar*. Thus image001.tif may have a copy of all embedded metadata stored in a separate file called image001.xmp.