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Technical Guidelines for Digitizing Cultural Heritage Materials: Creation of Raster Image Master Files

For the Following Originals - Manuscripts, Books, Graphic Illustrations, Artwork, Maps, Plans, Photographs, Aerial Photographs, and Objects and Artifacts

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Table of Contents

List of Tables

I. INTRODUCTION

Context

The *Technical Guidelines for Digitizing Cultural Heritage Materials: Creation of Raster Image Master Files* represents shared best practices followed by agencies participating in the Federal Agencies Digitization Guidelines Initiative (FADGI) Still Image Working Group for digitizing cultural heritage materials. This group is involved in a cooperative effort to develop common digitization guidelines for still image materials (such as textual content, maps, and photographic prints and negatives) found in cultural heritage institutions.

These *Guidelines* were prepared by members of the working group during the winter of 2009-2010. This document draws substantially on the National Archives and Records Administration's *Technical Guidelines for Digitizing Archival Records for Electronic Access: Creation of Production Master Files – Raster Images* (June 2004), but has been revised and updated in several areas to reflect the current recommendations of the working group and to reflect changes that have occurred in the digitization field during the last five years. Readers will find updated sections covering equipment and image performance metrics, quality management, and metadata in this revision.

For more information on the activities of the FADGI Still Image Working Group, please see http://www.digitizationguidelines.gov/.

Purpose

One of the tasks of the FADGI Still Imaging Working Group is to develop digital imaging guidelines that encourage and reflect collaborative digitization practices among federal agencies (and other interested institutions) in order to provide the public with images of uniform quality, and to provide a common set of practices and technical benchmarks for digitization service providers and manufacturers.

In the context of the work of the FADGI Still Imaging Group, some of the primary objectives of these *Guidelines* are to:

- Provide an approach to digitization that is practical today
- Describe technical parameters that promote a "well-defined" imaging environment
- Provide a consistent approach to imaging and metadata collection that will be appropriate for a wide range of outputs and purposes
- Define a common set of quality or performance metrics to be used in describing and evaluating the digital object, as well as methods of validating those measures to defined requirements
- Lay the groundwork for issues the Still Imaging Working Group intends to focus on in the coming months for potential incorporation into these *Guidelines*, including: metric aims and limits for imaging performance and quality specifications; color encoding accuracy; master and derivative file formats; transmissive image analysis targets; full lifecycle quality management plan; objective and subjective image performance analysis, and embedded/minimal metadata, among others

These *Guidelines* define approaches for creating high quality digital copies of originals used primarily for facilitating online access and hardcopy reproduction. They *may* be considered appropriate for preservation purposes (to create copies that could replace the original), but this largely depends on the local or internal policies of an organization. Therefore, the recommendations in this document may not be appropriate for all preservation uses (for example, scientific analysis).

Master files

These *Guidelines* provide technical approaches to the creation of raster image (pixel-based) master files. In creating master files, the primary objective is to produce digital images that look like the original items and to create a "reasonable reproduction" without enhancement. However, practice may vary from institution to institution regarding the amount of processing or editing that is performed on master files.

In general, master files have the following attributes:

- Maintain the essential features and information of the original
- Represent the best copy produced by a digitizing organization, with *best* defined as meeting the objectives of a particular project or program
- Represent digital content that the organization intends to maintain and manage for the long term
- Are created primarily for the production of a range of copies used for specific purposes (such as derivatives and duplicates)
- Document the image at the time of scanning, not what it may once have looked like if restored to its original condition

Institutions may create one or more digital master copies 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 geared for any specific output. If digitization is done to 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. If digitization is done to meet the alternative minimum image parameters and all other requirements, the master image files should be usable for many access applications, particularly for web usage and reproduction requests.

Generally, given the high costs and effort for digitization projects, we do not recommend digitizing to anything less than the alternative minimum image parameters. This assumes availability of suitable high-quality digitization equipment that meets the assessment criteria described (see the section on Quantifying Scanner/Digital Camera Performance) and produces image files that meet the minimum quality described in the *Guidelines*. If digitization equipment fails any of the assessment criteria or is unable to produce image files of minimum quality, then it may be desirable to invest in better equipment or to contract with a vendor for digitization services.

SCOPE

The focus of the *Guidelines* is on historical, cultural and archival materials. The scope is limited to digitization practices for still image materials only (e. g., textual content, maps, photographic prints and negatives).

The *Guidelines* are intended to be informative, not prescriptive. We acknowledge that this document does not address the entire range of imaging quality parameters (such as noise, distortion, etc.), but these topics will be incorporated as the Still Image Working Group identifies recommendations in these areas. The Working Group has produced a "Gap Analysis" document that identifies and prioritizes digitization activities that are not currently defined within existing agency guidelines, or are not adequately addressed by existing guidelines. The Gap Analysis contains topics that the Working Group intends to investigate and provide as updates and recommendations in future versions of these *Guidelines*.

The current Gap Analysis can be found on the FADGI website at:
http://www.digitizationguidelines.gov/stillimages/documents/Gap.html.

We hope to provide a technical foundation for digitization activities, but further research will be necessary to make informed decisions regarding all aspects of administrative, operational, and technical issues surrounding the creation of digital images. These guidelines provide a range of options for various technical aspects of digitization primarily relating to image capture, but do not recommend a single approach.

The following topics are addressed in this document:

- Digital image capture for still images – creation of master files, image parameters, digitization environment, color management, etc.
- Color encoding accuracy – color space, color temperature for imaging and viewing, quality of linear vs. area arrays, and quality of different interpolation algorithms

- Digital Image Performance – development of operational metrics and criteria for evaluating digital image characteristics for purposes of investigation or for quality control purposes, including metrics and criteria for resolution, noise, color encoding, misregistration, etc. of multi-bit images
- Example workflow processes – includes guidelines for image processing, sharpening, etc.
- Minimum metadata – we have included a discussion of metadata to ensure a minimum complement is collected/created so master image files are renderable, findable, and useable
- File formats – recommended formats, encodings of master files, etc.
- Approaches to file naming
- Basic storage recommendations
- Quality management – quality assurance and quality control of images and metadata, image inspection, acceptance and rejection, and metrology (ensuring devices used to measure quality or performance are giving accurate and precise readings), among others.

The following aspects of digitization projects are not discussed in these guidelines:

- Project Scope – defining goals and requirements, evaluation of user needs, identification and evaluation of options, cost-benefit analysis, etc.
- Selection – criteria, process, approval, etc.
- Preparation – archival/curatorial assessment and prep, records description, preservation/conservation assessment and prep, etc.
- Descriptive systems – data standards, metadata schema, encoding schema, controlled vocabularies, etc.
- Project management – plan of work, budget, staffing, training, records handling guidelines, work done in-house vs. contractors, work space, oversight and coordination of all aspects, etc.
- Access to digital resources – web delivery system, migrating images and metadata to web, etc.
- Legal issues – access restrictions, copyright, rights management, etc.
- IT infrastructure – determination of system performance requirements, hardware, software, database design, networking, data/disaster recovery, etc.
- Project Assessment – project evaluation, monitoring and evaluation of use of digital assets created, etc.
- Digital preservation – long-term management and maintenance of images and metadata, etc.
- Digitization of audio/visual and moving image materials
- Management of "born-digital" materials

A companion FADGI document, *Digitization Activities – Project Planning and Management Outline*, provides a conceptual outline of general steps for the planning and management of digitization projects, and addresses some of the topics listed above. This document is available at http://digitizationguidelines.gov/stillimages/documents/Planning.html

The intended audience for these *Guidelines* includes those who will be planning, managing, and approving digitization projects, such as archivists, librarians, curators, managers, and others, as well as practitioners directly involved in scanning and digital capture, such as technicians and photographers. The topics in these *Guidelines* are inherently technical in nature. For those working on digital image capture and quality control for images, a basic foundation in photography and imaging is essential. Generally, without a good technical foundation and experience for production staff, there can be no claim about achieving the appropriate level of quality as defined in these guidelines.

Revisions

These *Guidelines* reflect current best practices shared by members of FADGI, but we anticipate they will change as technology and industry standards, as well as institutional approaches, improve and change over time. As the technical arenas of conversion, imaging, and metadata are highly specialized and constantly evolving, we envision these *Guidelines* to be a continually evolving document as well. The *Guidelines* will be collectively reviewed by participating agencies at regular intervals and updated as necessary.

We welcome your comments and suggestions.

Please note that the **online version** of the *Guidelines* is considered to be the official document.

II. TECHNICAL OVERVIEW

Raster Image Characteristics

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 spaced and the higher the number of pixels overall. The lower the spatial resolution, the more widely 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 used often 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. When specifying a desired file size, it is always necessary to provide both the resolution and the image dimensions; ex. 300 ppi at 8"x10" or even 300 ppi at original size.

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. Also, depending on the intended usage of the master files, there may be a practical limit to how much fine detail is actually needed.

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 $2^1 = 2$.

The 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. However, at this time, monitors for viewing images and output devices for printing images all render high-bit images at 8-bits per pixel, so there is limited practical benefit to saving high-bit images and no way to verify the accuracy and quality of high-bit images. Also, it is best to do a good job during digitization to ensure accurate tone and color reproduction, rather than relying on post-scan correction of high-bit images. Poorly done high-bit imaging has no benefit.

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 LAB (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).

LAB 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 LAB mode is that it is matched to human perception, and also LAB mode does not require color profiles (see section on color management). Disadvantages of LAB 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. While theoretically LAB 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 Adobe RGB 1998 color profile (or, alternatively, an sRGB color 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.

Digitization Environment

Our recommendations and the ISO standards referred to below are based on using CRT monitors; however, the criteria specified below also applies to LCD monitors, as LCDs have now replaced CRTs in most imaging environments.. Be aware that inexpensive LCD monitors may have artifacts that make it difficult to distinguish image quality problems in the image files, and the appearance of colors and monitor brightness can shift with the viewing angle of the LCD panel. We recommend using a high-end LCD monitor designed for the graphic arts, photography, or multimedia markets.

Viewing Conditions

A variety of factors will affect the appearance of images, whether displayed or printed on reflective, transmissive or emissive devices or media. Those factors that can be quantified must be controlled to assure proper representation of an image.

We recommend following the guidance in the following standards-

- ISO 3664 Viewing Conditions- For Graphic Technology and Photography

  Provides specifications governing viewing images on reflective and transmissive media, as well as images displayed on a computer monitor without direct comparison to any form of the originals.
- ISO 12646 Graphic Technology – Displays for Colour Proofing – Characteristics and Viewing Conditions

  Provides specific requirements for monitors and their surrounds for direct comparison of images on a computer monitor with originals (known as soft proofing).

NOTE: The following are common parameters controlled by users, however, refer to the standards for complete requirements and test methods. In particular, ISO 12646 specifies additional hardware requirements for monitors to ensure a reasonable quality level necessary for comparison to hardcopy.

Monitor Settings, Light Boxes, and Viewing Booths

We assume the assessment of many digital images will be made in comparison to the originals that have been digitized, therefore ISO 12646 should be followed where it supplements or differs from ISO 3664.

We recommend digital images be viewed on a computer monitor set to 24 bits (millions of colors) or greater, and calibrated to a gamma of 2.2.

ISO 12646 recommends the color temperature of the monitor also be set to 5000K (D50 illuminant) to match the white point of the illumination used for viewing the originals.

Monitor luminance level must be at least 85 cd/m^2, and should be 120 cd/m^2 or higher.

The computer/monitor desktop should be set to a neutral gray background (avoid images, patterns, and/or strong colors), preferably no more than 10% of the maximum luminance of the screen.

For viewing originals, we recommend using color correct light boxes or viewing booths that have a color temperature of 5000K (D50 illuminant), as specified in ISO 3664.

ISO 3664 provides two luminance levels for viewing originals, ISO 12646 recommends using the lower levels (P2 and T2) when comparing to the image on screen.

The actual illumination level on originals should be adjusted so the perceived brightness of white in the originals matches the brightness of white on the monitor.

The Room

The viewing 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.

Practical Experience

In practice, we have found a tolerable range of deviation from the measurements required in the ISO standards. When the ambient room lighting is kept below the limit set in ISO 12646, its color temperature can be lower than 5000K, as long as it is less than the monitor color temperature.

To compensate for environments that may not meet the ISO standards, as well as difficulties comparing analog originals to images on a monitor, the color temperature may need to be set higher than 5000K so that the range of grays from white to black appears neutral when viewed in the actual working environment. The higher color temperature may also be necessary for older monitors to reach an appropriate brightness, as long as neutrals don't appear too blue when compared to neutral hardcopy under the specified illumination.

Monitor Calibration

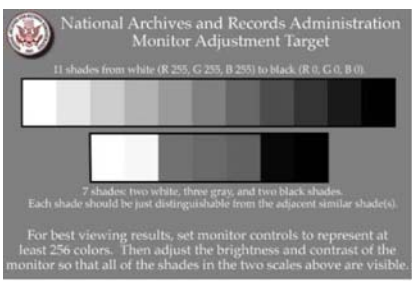
In order to meet and maintain the monitor settings summarized above, we recommend using LCD monitors designed for the graphic arts, photography, or multimedia markets.

A photosensor-based color calibrator (colorimeter or spectrodensitometer) and appropriate software (either bundled with the monitor or a third party application) should be used to calibrate the monitor to the aims discussed above. 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.

If using an ICC color managed workflow (see section on color management), an ICC profile should be created after monitor calibration for correct rendering of images.

The monitor should be checked regularly and recalibrated when necessary.

Using a photosensor-based monitor calibrator, however, does not always ensure monitors are calibrated well. Ten years of 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 the monitor is adjusted appropriately. Assess overall contrast, brightness, and color neutrality of the gray desktop. Also, evaluate both color neutrality and detail rendering in white and black areas. This can be done using an image target of neutral patches ranging from black to white and saved in LAB color mode (since LAB does not require an ICC profile and can be viewed independently of the color managed process). In addition, it may be helpful to evaluate sample images or scans of targets – such as the NARA Monitor Adjustment Target (shown below) and/or a known image such as a scan of a Kodak grayscale adjusted to the aimpoints (such as the NARA aimpoints 8-8-8/105-105-105/247-247-247) described below.



When the monitor is adjusted and calibrated appropriately, the NARA Monitor Adjustment Target (shown at left) and/or an adjusted image of a Kodak gray scale will look reasonably accurate. Images with ICC color profiles will display accurately within color managed applications, and sRGB profiled images should display reasonably accurately outside color managed applications as well. The NARA Monitor Adjustment Target and the gray scale aimpoints are based on an empirical evaluation of a large number of monitors, on both Windows and Macintosh computers, and represent the average of the group. Over the last fifteen of years calibrating and adjusting monitors in this manner, we have found the onscreen representation to be very good on a wide variety of monitors and computers.

Quantifying Scanner/Digital Camera Performance

Introduction

A key element in our approach to developing guidelines is to describe and document a common foundation of quality metrics for investigating and evaluating digital objects created through digital imaging.

The first table in this section (Part 1 – Taxonomy of Digital Imaging Performance) provides just that - a taxonomy of imaging performance. This hierarchical classification demonstrates the connections among related [existing] imaging characteristics, and provides context and a framework for the array of commonly used terms and the appropriate imaging standards available for the evaluation of digital image files.

The additional five tables in this section (Part II – Evaluation and Quality Control of Digital Imaging) build upon the framework set forth in the first table and provide operational metrics and criteria for evaluating digital image characteristics for purposes of investigation or, when used with specific requirements, or for quality control purposes.

Future work of the Still Image Working Group will rely on the information in these tables to establish quantitative guidelines using the described derivative metrics and evaluation criteria. The actual values that will be inserted into specific imaging guidelines will depend on the content to be digitized and the objectives for digitization.

Graphical symbols used in the row labeled "Evaluative Criteria *(units)*" indicate Primary, Secondary and Tertiary measures (see tables below).

These have meaning both across and within metrics. Across the metrics or image characteristics, they indicate the relative importance as a factor of image quality; from the highest (Primary) to the lowest (Tertiary).

The same concept applies within the measurement for a given metric. Taking SFR as an example, Max SFR gain is suggested as the Primary Measure under Sharpening, and Sign of SFR slope as a Secondary Measure. There are also two additional informational tiers included in the table. One of these provides a listing of related descriptive terms that may be more commonly known to users. The bottom-most tier provides a list of possible causes of failure related to a particular metric.

A a short primer and overview on imaging science is available as a Powerpoint at http://digitizationguidelines.gov/stillimages/presentations.html

Part 1 - Taxonomy of Digital Imaging Performance

See subsequent pages for information on
definitions, candidate evaluation criteria, related descriptive terms, and failure causes

Foundation Metrics	Signal										Signal-to-Noise Ratio	Noise										
Engineering Metrics	**OECF** (Opto-Electronic Conversion Function)				**SFR** (Spatial Frequency Response)							Radiometric Distortion **NPS** (Noise Power Spectrum)						Geometric Distortion				
												Total Noise				*Chroma Noise*						
												Temporal	*Fixed pattern*									
Derivative Metrics	***Speed / Sensitivity***	***Tone, Exposure***	***White Balance/ Neutrality***	***Color Encoding Accuracy***	*Sampling Rate*	*Resolution*	*Sharpening*	*Acutance*	*Flare*	*Depth of Focus*	*Dynamic Range*	*Random (stochastic)*	*Banding/Streaking (deterministic)*	*Defects (stochastic)*	*Non-uniformity (deterministic)*	*Color Uniformity (deterministic)*	*Color SFR Uniformity (deterministic)*	*Regional (deterministic)*	*Color Misregistration (deterministic)*	*Aliasing (deterministic)*	*Spatial SFR Uniformity (deterministic)*	*Pincushion/Barrel (deterministic)*

* While imaging noise is generally considered to be of a random or stochastic granular nature (e.g., photographic film grain), it can actually take many forms. We have chosen to categorize it in both by its deterministic and stochastic behaviors.

Part II - Evaluation and Quality Control of Digital Imaging
- SIGNAL -

Engineering Metrics	**OECF – Opto Electronic Conversion Function (ISO 14545)** TTF – Tone Transfer Function TRC – Tone Reproduction Curve *definition* : Average large area digital response of an electronic imaging device to light stimuli			
Derivative Metrics	**Sensitivity** (ISO 12232) *definition:* The reciprocal of the amount of light necessary to achieve a desired output response.	**Tone and Exposure** *definition* : characteristic behavior of large area digital output response (count value) to spectrally neutral input stimuli (gray patch)	**White Balance/Neutrality** *definition* : equivalence of large area color channel output responses to a range of spectrally neutral input stimuli	**Color Encoding/Rendering Accuracy** *definition:* The difference between selected physically measured input colors and their intended output rendering from a given color space.
Related descriptive term	– Responsivity – Speed – Exposure Index (EI)	– Too dark/light – Under/over exposed – No shadow/highlight detail – Clipping – Contrast – Exposure Accuracy	- Color cast - Gray balance	– Over/under saturated colors – Color balance is wrong – Memory colors are not correct – Color Accuracy – Color Saturation
Evaluation Criteria *(units)* ●=Primary ◒=Secondary ○=tertiary	●: Saturation based speed *units: TBD* ◒: Noise based speed *units: TBD* ○: Exposure Index, Standard Output Sensitivity	●: Average, median, maximum or RMS deviation from aim for neutral patches of interest. *units:* Count Values, ΔL*, Density, F-stops ◒: Deviation from a reference OECF gamma value *units:* gamma (unitless)	●: Average, median, maximum, or RMS deviation from aim between color channels (R-G, R-B, G-B) for neutral patches of interest. *Units (●):* Count Values, $\Delta E_{a^*b^*}$, *Units (◒):* Delta C, Delta H	●: Average, median, maximum, or RMS deviation from aim for chromatic patches of interest *Units (●):* Count Values, Delta E (ΔE), Delta E ($\Delta E_{a^*b^*}$), *Units (◒):* Delta C, Delta H
Possible failure causes	- Inefficient imaging detector	–Auto-contrast failures –Inappropriate black/white point calibration. - Wrong gamma selection or tone aim	– Poor auto-white balance algorithm – Bad white /black point calibration – Sparse gray patch balancing – Color Balance – Strongly colored environmental surround	– Color profile tweaked for preference – Wrong color profile intent – Wrong color profile chosen/embedded – Color profile assumptions inconsistent with practice (i.e. lighting quality, gamma, intent, etc.) – Environmental : highly chromatic color surround/clothing

- SIGNAL -

Engineering Metric	SFR - Spatial Frequency Response – (ISO 12233, ISO 16067-1, ISO 16067-2, ISO 15524) MTF – Modulation Transfer Function *definition* : A spatial frequency descriptor of an imaging system's ability to maintain the relative contrast of input stimuli					
Derivative Metrics	**Sampling Rate** *Definition:* The reciprocal of the center-to-center distance between closest adjacent pixels. The number of samples per unit distance.	**Resolution** *Definition: An* imaging system's ability to resolve finely spaced detail. The level of spatial detail that can resolved in an image	**Sharpening** *Definition* :Amplification of the SFR by means of image processing to achieve sharper appearing images	**Acutance** *Definition*: An objective SFR based metric that is used as a correlate to perceived image sharpness.	**Flare** *Definition:* a skirty or wide spreading of light.	**Depth of Focus** *Definition: The distance along the optical axis that remains within acceptable focus.*
Related descriptive term	- Megapixels - Dots per inch (dpi) - Pixels per inch (ppi) - Sampling frequency	– Blurred – Soft – Sharp – In/Out of focus – Spherical aberration – Spatial detail	– Oversharpening (haloing, garish edges) – Snap – Edgy, Sharp, Crisp – Edge enhancement - Unsharp masking	- Sharp	– Low contrast – Hazy – Ghosting - Veiling flare - Glare - Integrating cavity effect (ICE)	- Depth of field - Circle of confusion - Focus tolerance - Hyperfocal distance
Evaluation Criteria (*units*) ●=Primary ◒=Secondary ○=tertiary	●: The number of captured or delivered pixels per unit distance in both the horizontal and vertical dimensions *units:* dots-per-inch, pixels-per-inch	●: 10% sampling efficiency based on Luminance SFR *units:* (unit less) ●: Min/Max 10% spatial frequency limits of Luminance SFR *units:* dpi, cycles/mm ◒: Min/Max 50% spatial frequency limits of Luminance SFR *units:* dpi, cycles/mm	●: Max SFR gain *units:* % SFR response ◒: Sign of SFR slope *units :* positive/negative slope value	●: Area under the SFR as weighted by an appropriately chosen visual contrast function. *units:* TBD	● % Flare - *units: (unit less)*	●: Distance along the optical axis that remains in acceptable focus *units:* inches, mm.
Possible failure causes	- Poor calibration technique - Wrong choice of units at calibration	- Poor (auto) focus - Poor optics - Poor choice of aperture stop - Mechanical vibration - Over aggressive noise control	- Over aggressive sharpening settings - Insufficient signal to amplify - Thinking that if a little is *good* then *more* must be better.	- Optical performance exceeds sampling rate	- Dirty lens - Light source directed into lens - Poor quality lens - Stray light	- Poor F-number choice

– NOISE –

Engineering Metric	– Radiometric Distortion – *definition:* The deviation of any given spatially imaged point from an aim radiant energy value relative to the input object.					
Derivative Metrics	Noise Power Spectrum (NPS) *Total Noise* *Definition* : A spatial frequency descriptor of the sources of radiometric noise of an imaging component or system				Chromatic Noise *Definition* : The inter-color channel radiometric deviations relative to an identified aim	
Derivative Metrics	Temporal Noise	Fixed Pattern Noise			Color Uniformity (deterministic) *Definition* : A difference in large area uniformity/shading between color channels	Color SFR uniformity (deterministic) *Definition:* The differential spread of light between color channels.
	Random (stochastic) *Definition* : The root mean square deviation (std. deviation) of both temporal and fixed pattern noise for a single color channel	Banding/ Streaking (deterministic) *Definition* : One dimensional patterns	Defects (stochastic) *Definition* : point or clusters of defective or poorly corrected pixels	Non-Uniformity/ Shading (deterministic) *Definition:* A deviation in the effective illumination over a capture device's field of view; usually with lower illumination near the field's outer extent.		
Related descriptive term	- Temporal noise - Grain - Shot noise - Read noise - White noise	- Stripes - Banding - Streaking	- Hot, Cold, or Dead Pixels - Wounded Pixels - Blinkers	- Vignetting - Relative illumination	- Rainbows	– Colored edges – Color Bleed – Fringing
Evaluation Criteria *(units)* ●=Primary ◖=Secondary ○=tertiary	●: RMS deviation of pixel values in terms of selected metric(i.e., counts, density, Luminance) over an identified region of interest *units:* counts, density, Luminance	●: The relative amount of variance or noise power that a selected spatial frequency band contributes to the total noise. *units:* TBD	●: The number or size of defects per unit sensor area. *units:* # of defects/unit sensor area	●: The percent deviation of several large area luminance measurements over the field of view relative to the average of those measurements. *units:* % Luminance difference (unit less)	●: The percent deviation of several large area chroma measurements over the field of view relative to the average of those chroma measurements. *units:* % chroma difference (unit less)	●: The difference in SFR response between selected color channels. *units:* % deviation in SFR response relative to the highest measured SFR (unit less)
Possible failure causes	- Aggressive digital signal amplification or processing - High ISO speed selection - High throughput workflows	- Poor sensor calibration - dust/dirt on linear array sensor - poor sensor calibration	- dust on sensor - poor sensor fabrication hygiene - poor sensor calibration	- poorly designed optics - non-uniform lighting	- Chief ray angle (CRA) mismatch between optics and sensor - Non-uniform color coatings at sensor fabrication.	- Poor optical design or performance

- NOISE –

Engineering Metric	– Geometric/Spatial Distortion – *definition:* The deviation of any imaged point from its intended or aim spatial position relative to the input object.				
Derivative Metrics	**Field height diagram** (deterministic) *Definition:* A change in magnification of an imaged object as a function of field position.	**Regional** (deterministic) *Definition* :A locally varying deviation in intended spatial position of an imaged object	**Color Misregistration** (deterministic) *Definition:* color-to-color spatial dislocation of otherwise spatially coincident color features of an imaged object.	**Aliasing** (deterministic) *Definition* : A sampling effect that leads to spatial frequencies being falsely interpreted as other spatial frequencies	**Spatial SFR uniformity (luminance)** (deterministic) *Definition:* A difference in luminance SFR as a function of optical field position
Related descriptive term	– Pincushion – Barrel – TV distortion – Field Curvature – Skew – Keystoning	- Wobble - Jitter	- Colored edges - Chromatic aberration - Lateral chromatic error(LCE)	– Jaggies – Moiré – Pixelization – Potential for aliasing	- Blurred or soft look near corners of image - Spherical Aberration - Coma
Evaluation Criteria (*units*) ●=Primary ◓=Secondary ○=tertiary Derivative Metrics	●: The amount of distortion derived from a selected position on a field distortion diagram (typical for single shot devices) *units:* % distortion (unit less) ◓: Percent difference in the number of pixels in the Horizontal and vertical directions for a square object dimensions.(Typical for scanning backs or linear scan devices) *units:* % distortion (unit less)	●: RMS deviation in terms of pixels or distance relative to an extended linear feature *units:* rms deviation in pixels or distance relative to an identified linear feature. *units*: pixels, distance	●: The amount of spatial dislocation between any two selected color channels. *units:* # pixels, # inches, # mm	●: SFR response at half-sampling frequency. *units:* % SFR response ○: Area under the SFR beyond the half-sampling frequency. *units: TBD*	◓: % deviation in SFR response at a selected spatial frequency across the field of view *units: RMS SFR response Min/Max SFR response*
Possible failure causes	- Poorly designed optics - Mismatched sampling rates in the horizontal and vertical directions	- Mechanical fluctuations or dislocations in the movement of an imaging sensor.	- Poor optical design or assembly - Poor color algorithm reconstruction in RGB single shot cameras. - Poor optical alignment.	- Optical performance exceeds the sampling frequency capabilities. - Lack of optical pre-filtering	- Poor optical design or assembly

- NOISE -

Engineering Metric	– Radiometric Distortion – *definition:* The deviation of any given spatially imaged point from an aim radiant energy value relative to the input object.					
Derivative Metrics	Noise Power Spectrum (NPS) *Total Noise* *Definition* : A spatial frequency descriptor of the sources of radiometric noise of an imaging component or system				Chromatic Noise *Definition* : The inter-color channel radiometric deviations relative to an identified aim	
Derivative Metrics	Temporal Noise	Fixed Pattern Noise			Color Uniformity (deterministic) *Definition* : A difference in large area uniformity/shading between color channels	Color SFR uniformity (deterministic) *Definition:* The differential spread of light between color channels.
	Random (stochastic) *Definition* : The root mean square deviation (std. deviation) of both temporal and fixed pattern noise for a single color channel	Banding/ Streaking (deterministic) *Definition* : One dimensional patterns	Defects (stochastic) *Definition* : point or clusters of defective or poorly corrected pixels	Non-Uniformity/ Shading (deterministic) *Definition:* A deviation in the effective illumination over a capture device's field of view; usually with lower illumination near the field's outer extent.		
Related descriptive term	- Temporal noise - Grain - Shot noise - Read noise - White noise	- Stripes - Banding - Streaking	- Hot, Cold, or Dead Pixels - Wounded Pixels - Blinkers	- Vignetting - Relative illumination	- Rainbows	– Colored edges – Color Bleed – Fringing
Evaluation Criteria (*units*) ●=Primary ●=Secondary ○=tertiary	●: RMS deviation of pixel values in terms of selected metric(i.e., counts, density, Luminance) over an identified region of interest *units:* counts, density, Luminance	●: The relative amount of variance or noise power that a selected spatial frequency band contributes to the total noise. *units:* TBD	●: The number or size of defects per unit sensor area. *units:* # of defects/unit sensor area	●: The percent deviation of several large area luminance measurements over the field of view relative to the average of those measurements. *units:* % Luminance difference (unit less)	●: The percent deviation of several large area chroma measurements over the field of view relative to the average of those chroma measurements. *units:* % chroma difference (unit less)	●: The difference in SFR response between selected color channels. *units:* % deviation in SFR response relative to the highest measured SFR (unit less)
Possible failure causes	- Aggressive digital signal amplification or processing - High ISO speed selection - High throughput workflows	- Poor sensor calibration - dust/dirt on linear array sensor - poor sensor calibration	- dust on sensor - poor sensor fabrication hygiene - poor sensor calibration	- poorly designed optics - non-uniform lighting	- Chief ray angle (CRA) mismatch between optics and sensor - Non-uniform color coatings at sensor fabrication.	- Poor optical design or performance

Tests for Objective Performance of Scanners/Cameras

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 some performance claims in product literature are often overstated. If test results are not available, then try to scan test targets during a demonstration and consider having the analyses performed by a contract 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. These test methods can be used for objective assessment of scanner or digital camera/copy system performance:

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

These standards can be purchased from ISO at http://www.iso.ch, http://webstore.ansi.org/ within the U.S.,. 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. See http://digitizationguidelines.gov/stillimages/digstandards.html for a comprehensive list of standards related to digital imaging performance.

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. Unfortunately, at this time image analysis software is expensive and complex making it difficult to perform all the tests needed to properly quantify scanner/digital camera performance. Also, there is a range of test targets needed for these tests and they can be expensive to purchase. More information on reference targets is provided below.

No digitization equipment or system is perfect, they all have trade-offs in regards to 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). Compromises and tradeoffs are a normal part of real-world imaging. In such cases, it is important to evaluate the physical characteristics of the material to be imaged as well as the objectives behind the imaging project (e.g., broader general access, space savings, research, etc.)

Test Frequency and Equipment Variability

After equipment installation and familiarization with the hardware and software, an initial performance capability evaluation should be conducted to establish a baseline for each specific digitization device. At a minimum, this benchmark assessment would include, for example:

- resolution performance for common sampling rates (e.g. 300, 400, 600, and 800 ppi for reflection scanning)
- OECF and noise characterization for different gamma settings
- lighting and image uniformity

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.

A full suite of tests should be conducted to quantify the performance of digitization systems. Some tests probably only need to be redone on an infrequent basis, while others will need to be done on a routine basis. Depending on the performance consistency of equipment, consider performing tests using production settings on a weekly basis or for each batch of originals, whichever comes first. You may want to perform appropriate tests at the beginning of each batch and at the end of each batch to confirm digitization was consistent for the entire batch. Work at obtaining consistent results (precision), and work on the optimizing the performance levels (accuracy) next.

Scanner/digital camera performance will vary based on actual operational settings. Tests can be used to optimize scanner/camera settings. The performance of individual scanners and digital cameras will vary over time (see test frequency above). 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 appropriate 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.

Digital Imaging – Objective Performance Measures

Introduction to Objective Performance Measures and Guidelines

Following are descriptions on the aspects of digital image performance that can be measured objectively and evaluated for quality against established requirements. While this is not a complete list of possible performance measures, we feel it can provide an adequate characterization of both camera/scanner capabilities as well as evaluating individual images in an objective manner. The guidelines for objective performance is intended to be part of a quality management program that includes subjective visual inspection, calibration of devices, validation of metadata and file encodings, among other quality-related tasks.

The graphics accompanying the descriptions were generated using the Digital Image Conformance Evaluation (DICE) system object-level target. The development of the DICE system was sponsored by this Initiative. While other targets may be used to generate similar image performance data, this data was generated using the target design from Image Science Associates. The design is not proprietary and the various features are compatible with ISO standards for evaluation.

The following are individual imaging performance criteria that provide the aim point and tolerances for imaging specifications based on a four-tiered performance model. These performance levels can be combined by the user for their particular use and imaging objectives. For instance, a sample specification is shown in Table 1. On the left is the metric name followed on the right by a 1 to 4-star specification code. In italics to the right is a description of the code. The performance level is largely driven by the TOLERANCE (i.e. allowable variability about the AIM). The tighter the tolerance level, the better the performance, and generally, the higher the cost. The "Qualifier" column specific user preferences with regard to the aims or tolerance.

Under the Still Image Working Group, there is a Categories and Objectives sub-group. This sub-group is in the process of developing a matrix that will map to the very type of multi-tier model used in the Quantitative Performance Guidelines. The work of this sub-group can be viewed here - http://digitizationguidelines.gov/stillimages/subcommittees.html

his imaging performance guideline model allows for real-world projects where a strict tolerance in one metric does not necessitate strict tolerances across the board. As an example, using the system used in this document, a color critical project may require a minimum four-star performance level for **color encoding error**, but may only require a two-star performance level for **illuminance non-uniformity**.

Finally, the performance levels documented here were arrived at through several years of quantitative performance studies on a limited number of devices. As more data from field use is gathered and these guidelines increasingly adopted these performance level guidelines may change on user feedback.

Following is a description of the image characteristics that comprise the current Objective Performance Guidelines. All of the following characteristics are evaluated through the use of target (ground truth) data.

Objective Performance Measures Described

Tone Response Curve (TRC) ISO 14545 – Opto Electronic Conversion Function

The **Tone Response Curve** of a digital camera or scanner determines the lightness, darkness, and contrast of a displayed image. Each color channel (i.e. R, G, or B) has its own behavior. The key to consistent colors is to keep the individual RGB TRC curves as equal to each other as possible (see White Balance Error). The horizontal axis of the curve is called Density and is an objective measure of dark or light regions on the object. The lower the density, the lighter the region, and the higher the density, the darker the region.

On the vertical axis is the digital count value associated with those regions as captured by the camera or scanner. Setting the **white point** or **dark point** of a scan will affect the shape of this curve. **Gamma** is another term associated with the TRC and is a summary number for quickly communicating the overall contrast and lightness an image is likely to have upon display.

Many color encoding standards (i.e., Adobe RGB, sRGB, eciRGB, etc.) strictly define what the gamma value should be for a selected color space. For cultural heritage imaging these gamma values are often not adhered to because of the large variety of use cases and object characteristics. Therefore, these guidelines allow for any user defined TRC.

Whatever TRC is selected though, the important goal is maintain consistency and minimize variability. The lower the variability, the more consistent and manageable a product becomes. These guidelines assign a premium to low variability: the lower the workflow variability, the better the performance (i.e. higher "star" rating). Table 1 below gives suggested digital count value tolerances associated with each performance level and applies to the entire TRC. Fig. 1 on the following page illustrates how these tolerance levels apply to a user selected TRC aim of gamma of 2.2.

Tone Response - (OECF)		
Performance Level	AIM	TOLERANCE (8 bit equivalent) (applies to all density levels and color channels)
★★★★	consistent with chosen color space (e.g. Gamma = 1.8 or 2.2) or user defined	+/- 3 count levels
★★★		+/- 6 count levels
★★		+/- 9 count levels
★		> 9 count levels, < -9 count levels

Table 1 – TRC aim guidelines

Shown below are typical measured RGB TRCs using image targets and software. Note the allowable tolerance corridor for a two start performance level defined by the dashed line. The user selected aim curve (solid green) is for gamma 2.2. To better visualize the variability of all three channels relative to the selected aim TRC, a difference curve or delta-from-aim curve is often provided. Fig. 2 shows such a curve broken out for the individual color channels.

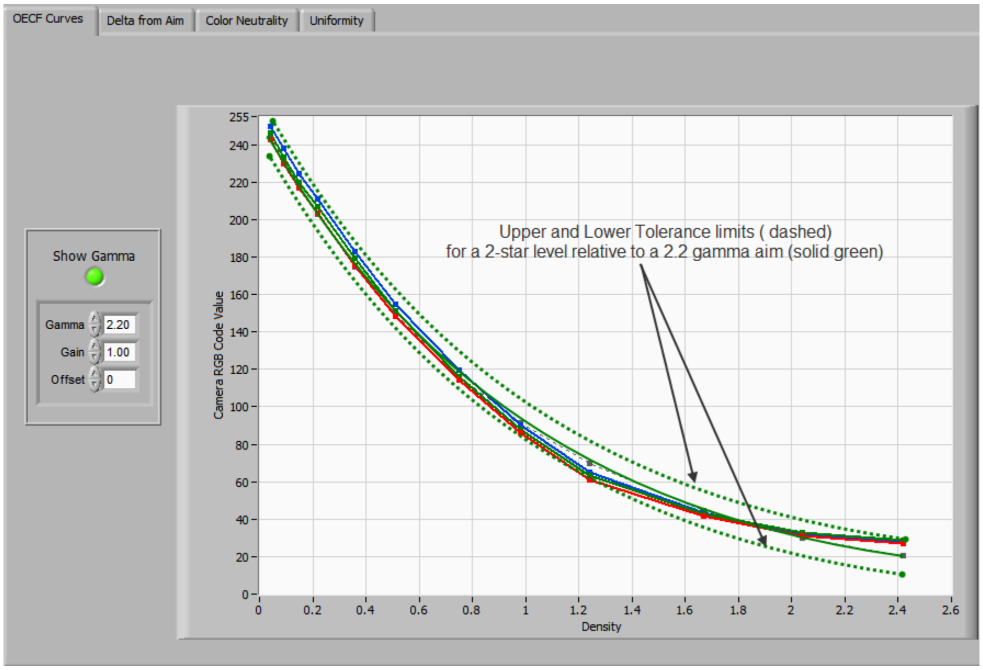


Fig. 1 – Measured TRC curves relative to a gamma 2.2 aim and tolerance limits

Because they provide an enlarged rendering of the performance variability, the plots of Fig. 2 are often of more utility in decision making. To provide a comparison to 3-star level performance, narrower corridor limits are also shown in Fig. 2. All three color channels fall within the tolerance corridor defined by the upper and lower dashed lines (i.e., limits) and therefore PASS the 2-star criteria. Several values fall outside the 3-star level corridor and would FAIL by that standard.

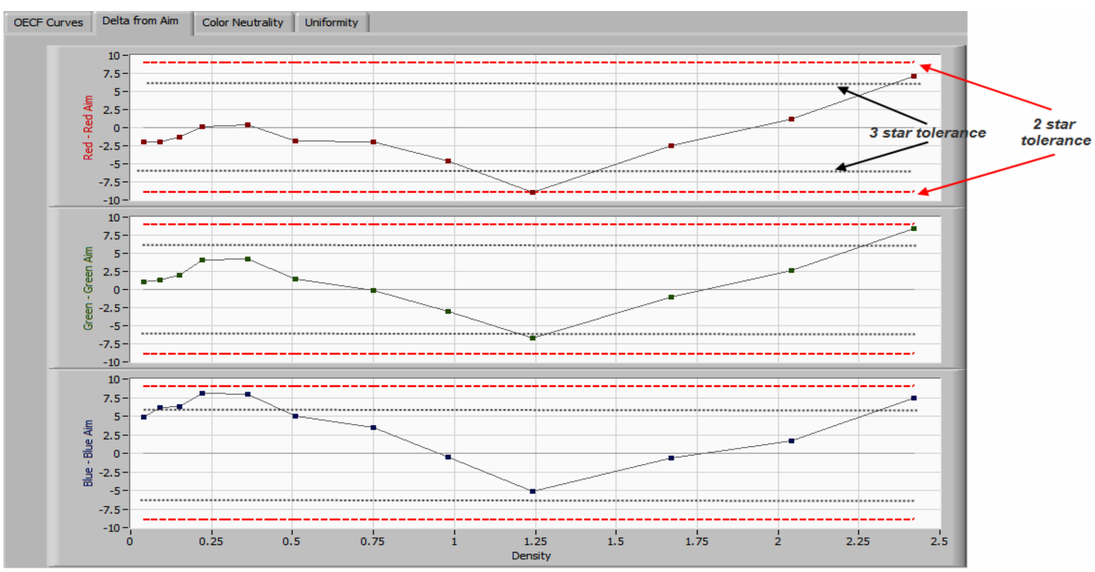


Fig. 2 – Delta from Aim plots for evaluating TRC compliance

White Balance Error

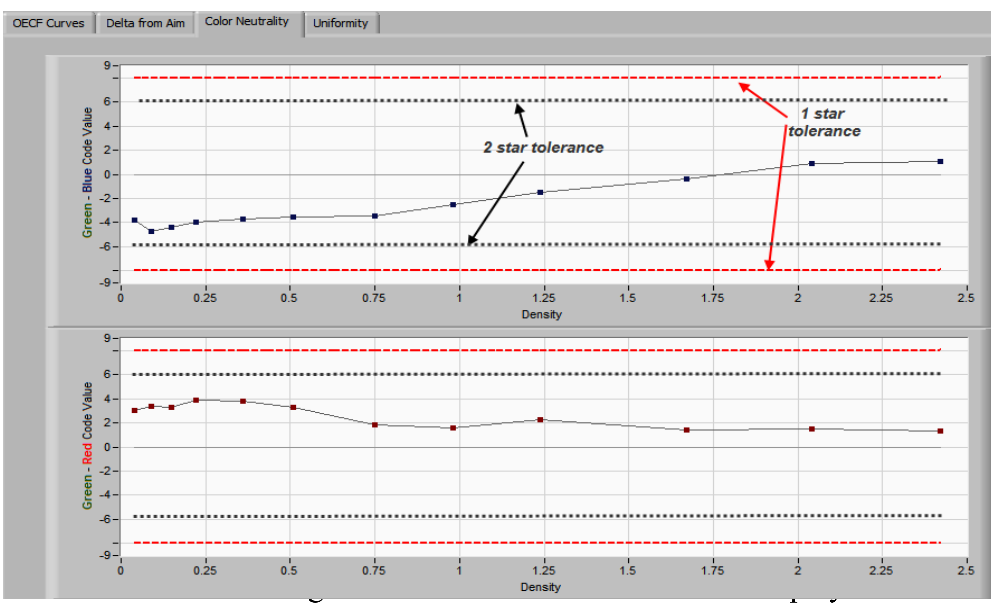
Eighty-five percent of good color management depends on low white balance errors. Analyzing the differences in digital count values between color channel TRC values for multiple gray patch values provides for **White Balance Error** measurement**.** Its calculation from TRC curves is quite easy. For a given gray patch value (twelve patches are used for this example) the difference in average count between the Green and Blue channels (G-B) and Green and Red channels (G-R) are calculated. These differences are then compared against the tolerance values of Table 2 to arrive at either a PASS or FAIL decision.

As with any error based criteria, the aim value is zero. One would like no difference in count value between color channels when evaluating the gray or neutral patch values. Suggested error tolerances for the starred performance levels are provided in Table 2.
For color critical work higher performance levels (i.e. low tolerance levels) may be necessary. For now, the error tolerances are applied uniformly across all density levels.
This is subject to change based on user experiences and defined use cases.

White Balance Error		
PERFORMANCE LEVEL	AIM	TOLERANCE - 8-bit equivalent (applies to G-B, G-R difference for all neutral density levels)
* * * *	0	± 3 count levels
* * *	0	± 4 count levels
* *	0	± 6 count levels
*	0	± 8 count levels

Table 2 – White Balance Error aim and tolerance guidelines

Figure 3 below illustrates a typical results display for White Balance Error. In this example, a 2-star performance rating is achieved. A 3-star level could have been achieved except for high errors at several of the low density values.



Illuminance Non-Uniformity

Two separate but inextricably linked imaging properties contribute to this perfomance metric. One of these, lighting uniformity, is a measure of the extent to which an object is evenly illuminated by a light source, even before being imaged by a camera or scanner. Generally the larger the field-of-view or object size the more difficult it is to achieve uniform lighting.

Upon being imaged, an effectcive lighting non-uniformity is introduced by the camera or scanner. This latter effect is often referred to as **shading** or **vignetting.** These guidelines refer to the combined and cascaded effect of these two effects in an imaging system as **illuminance non-uniformity**. Since the goal is to minimize illuminance non-uniformity, the aim value is zero.

Table 3 below provides guideline tolerances in terms of percentage.

Illuminance Non-uniformity		
Performance Level	AIM	TOLERANCE
★★★★	0	< 1%
★★★	0	< 3%
★★	0	< 5%
★	0	> 5%

Large area measurements for illuminance non-uniformity are taken at five different locations over the cameras field of view; one in the center and one each near the four corners of the field of view. These five measurements are combined into a single illuminance non-uniformity metric calculated by a [max.-min] to average value quotient depicted in Figure 4 below. The individual values of these five areas are also presented for completeness. Only the luminance weighted result is tested against.

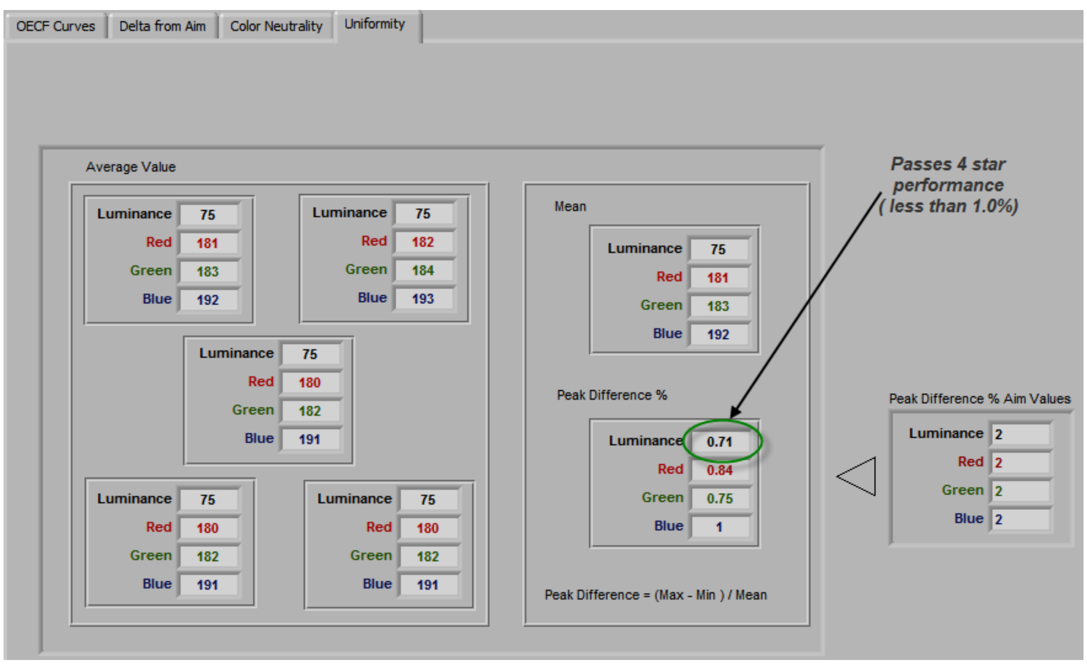


Fig. 4 – Illuminance Non-uniformity panel result

Color Encoding Error

Colors are encoded in digital images as combinations of red®, green (G), and blue (B) code values. These RGB triplets can be interpreted as physically measurable colors. A commonly accepted way to designate these physical colors is with another triplet of numbers called L*, a*, and b* values. The L* value indicates the lightness, while the a* and b* components, in combination, characterize the hue and saturation of a color. Taken together, the L*a*b* values define a color space where equal differences between points tend to equate to equal perceptual differences.

However code values are not measurement units, but L*a*b* values are. In order to transform code values into appropriate L*a*b* color values one must either designate a working color space or a capture device color profile that defines the recipe for this transformation. Either one of these can provide the mathematical path from three digital code values (RGB) to intended units of color measurement (L*a*b*). While there are other constraints to this transformation the above covers the majority of considerations for RGB to L*a*b* translation.

To measure how well any particular color patch on a target is being encoded by the camera or scanner one must know what the original L*a*b* values of those target color are. These can either be measured by the user, or are typically provided by the manufacturer of the target. **Color Encoding Error** measures the difference between what the actual target colors are and what they would be if the RGB values of those color patches are decoded according to a specified working color space standard or device color profile. **Delta E** (ΔE) is the unit for measuring this error.

Since multiple color and neutral patches of a target are analyzed, usually, average ΔE and maximum ΔE summary values are reported. Table 3 below provides guidelines for the average and maximum color encoding error using the ΔE_{2000} metric from the patches of the device or object level targets.

Color Encoding Error (Delta E 2000)					
Performance Level	AIM	TOLERANCE (choose option A or B)			
		A) Δ E (L*a*b*)		B) ΔE (a*b*)	
		max	avg.	max	avg.
★★★★	0	< 6	< 3	< 3	< 2
★★★	0	< 10	< 5	< 5	< 3
★★	0	< 15	< 10	< 8	< 6
★	0	> 15	> 10	> 8	> 6

Table 3 – Color encoding error limits for designated performance levels

Two choices for specifying color encoding error tolerances are provided. The one under Column A of Table 3 uses a formula where all three variables, (L*,a*,b*), are used in the ΔE calculation. This option may be used where strict adherence to a selected working color space is desired, particularly to the lightness component, L*.

In practice strict compliance to the L* definition of a working color space can yield unacceptable image quality upon display; especially for collection content with low dynamic ranges. For this reason, the Column B option may be chosen instead.

Fig. 5 illustrates a typical Color Encoding Error report using the ΔE_{2000} metric. Notice that the summary values for either the Column A or Column B specification selections are provided at the top of the graph. For either of these selections a 2-start performance level would be achieved. This level of performance may be suitable for projects that are not color critical. The large ΔE_{2000} differences between the red and black points of Fig. 5 indicate a lack of L* conformance of the color image encoding with respect to the selected working color.

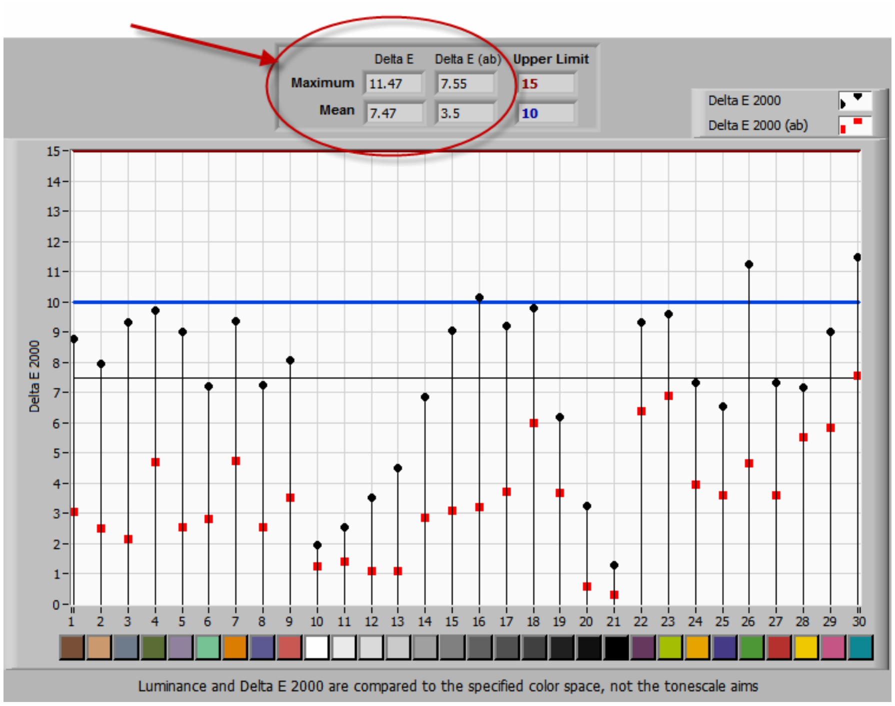


Fig. 5 – Color Encoding Error report using ΔE_{2000} for a Device level target image

Spatial Frequency Response (ISO 12233, 16067-1, & 16067-2)

Spatial Frequency Response (SFR) measures an imaging system's ability to maintain the relative contrast to increasingly finely spaced features. A number of important performance measures can be derived from this single function. Four of these are suggested for testing in these guidelines and are described briefly below.

- Closely spaced or **high frequency** features test the **limiting resolution** of an imaging system.
- An imaging systems response to moderately space or **mid-frequency** features provide insight on the ability to re-purpose an image for a variety of use cases without introducing artifacts.
- For digital imaging system it is even possible for the resolution to be too good thus introducing **aliasing** artifacts.
- As part of the processing that occurs on delivered image files, **sharpening** is often applied. Often these sharpening operations are over-aggressive and cause images to appear un-natural or synthetic.

Shown in Tables 4, 5, and 6 below are the suggested guidelines for the above four performance criteria that are derived from the SFR. Note that all these criteria apply only to the Luminance channel SFR response.

Spatial Frequency Response (SFR) - high frequency resolution (native response, no sharpening, Luminance channel only)			
Performance Level	AIM	TOLERANCE (for both horizontal and vertical directions equally)	
		lower limit sampling efficiency (luminance) or **limiting resolution**	upper limit SFR response at half sampling frequency **(Aliasing)**
★★★★	100% efficiency or 10% SFR response at the half sampling frequency	> 90% of half sampling	< 0.20 SFR response
★★★		> 85% of half sampling	< 0.30 SFR response
★★		> 75% of half sampling	< 0.40 SFR response
★		< 75% of half sampling	> 0.40 SFR response

Spatial Frequency Response (SFR) - mid-frequency resolution (native response, no sharpening, Luminance channel only)			
Performance Level	AIM	TOLERANCE (specified at half of selected dpi level or 50% the half-sampling frequency)	
		lower limit	upper limit
★★★★	0.50 SFR rsponse at 55% of half sampling frequency	> 40% of half sampling	< 60% of half sampling
★★★		> 35% of half sampling	< 65% of half sampling
★★		> 30% of half sampling	< 70% of half sampling
★		< 25% of half sampling	> 70% of half sampling

Table 5 - Suggested mid frequency SFR tolerances for specified performance levels

Sharpening - Single SFR point		
Performance Level	AIM	TOLERANCE
		Upper limit - any frequency between zero and half sampling values for the Luminance channel
★★★★	1.0 maximum SFR response	≤ 1.0
★★★		≤ 1.1
★★		≤1.2
★		>1.2

Table 6 - Suggested SFR sharpening limits for specified performance levels

The SFR of Fig. 6 illustrates how the limits of Tables 4 and 6 can be applied and interpreted. For **mid-frequency** testing the SFR PASSES the 3-star corridor but not the 4 star level. The **limiting resolution** or **sampling efficiency** test measured at the 10% SFR response level is excellent (4 star) and is appropriately bounded by the upper performance limit to minimize any potential aliasing artifacts.

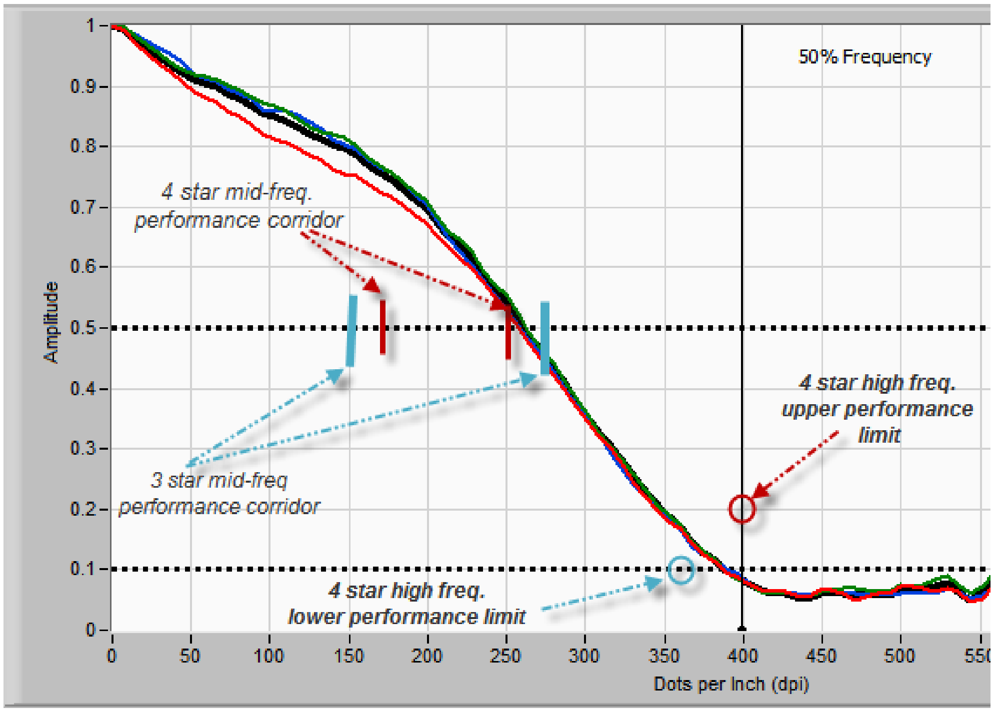


Fig. 6 – SFR example with mid and high frequency test limits

The specification for sharpening cited in Table 6 is meant to limit aggressive image sharpening that often creates haloing artifacts and un-natural appearing images. It is recognized that sharpening processing is often applied to delivered image files and when used in moderation is acceptable. This specification should only be used when sharpening operations are unavoidable or agreed upon by client and vendor. Fig. 7 illustrates SFRs exhibiting sharpening behaviors. The Luminance SFR (solid black line) in this example would be classified as a 3 star level.

There is a strong likelihood that if sharpening testing is invoked, the mid frequency limits of Table 5 will FAIL at even the lowest rating level. The same is likely to be true for the high frequency upper limit testing shown in the right hand column of Table 4.

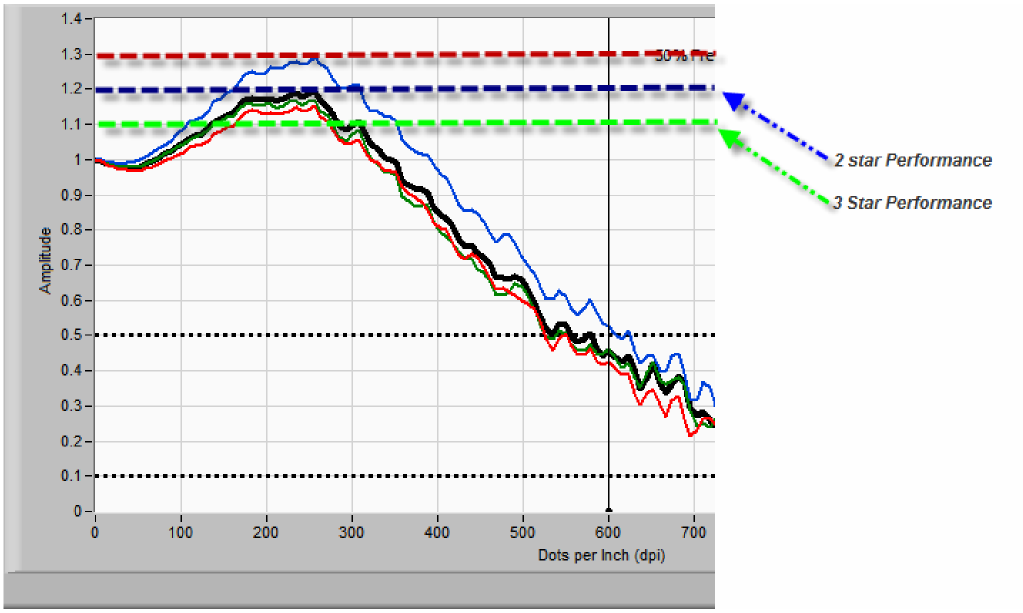


Fig. 7 – Illustration of sharpening behaviors in SFR Curves and performance levels

Finally, more unified approach to aims and tolerances for resolution is currently being investigated by specifying the full SFR behavior. While it is recognized that resolution and other metrics (illustrated here) are a single point summary measures derived from SFR, it is also accepted that more study and agreement is required before introducing full SFR guidelines, especially with respect to sharpening operators. Just as tone response specification moved from single patch metrics to a full OECF description, similarly single point resolution metrics will move to full SFR specification descriptor. Robust software tools and reporting methods also need to be developed before this can occur.

Noise (ISO 15739)

Noise is measured similar to the technique used for determining the TRC curve discussed previously. Instead of taking the average count value of all pixels associated with a region of interest(ROI) on a neutral target patch, the standard deviation of the all the count values is calculated instead. This is done for all twelve gray patches. The upper limit performance guidelines for noise are provided in Table 7 below.

Noise		
Performance Level	AIM	TOLERANCE (8 bit equivalent) (applies to Red, Green and Blue and all neutral patches)
★★★★	0.0 *(0.5)*	< 2.0 count levels (rms)
★★★	0.0 *(0.5)*	< 3.5 count levels (rms)
★★	0.0 *(0.5)*	< 5.5 count levels (rms)
★	0.0 *(0.5)*	> 7.0 count levels (rms)

Table 7 – Performance Guidelines for Noise

Note the parenthetical aim value of 0.5. While achieving zero noise in an imaging system is an admirable goal, in practice, such a value is more an indication of aggressive noise cleaning or signal clipping operations. Both are to be avoided. Images with noise levels below 0.5 should be treated suspiciously since such operations may have been applied.

The noise graphs of Fig. 8 are illustrated for all three color channels. While the green and blue channels achieve a 4-start level (i.e., less than 2.0 rms counts for all density levels) notice that the higher density patches in the red channel are higher and only achieve
level 3 performance.

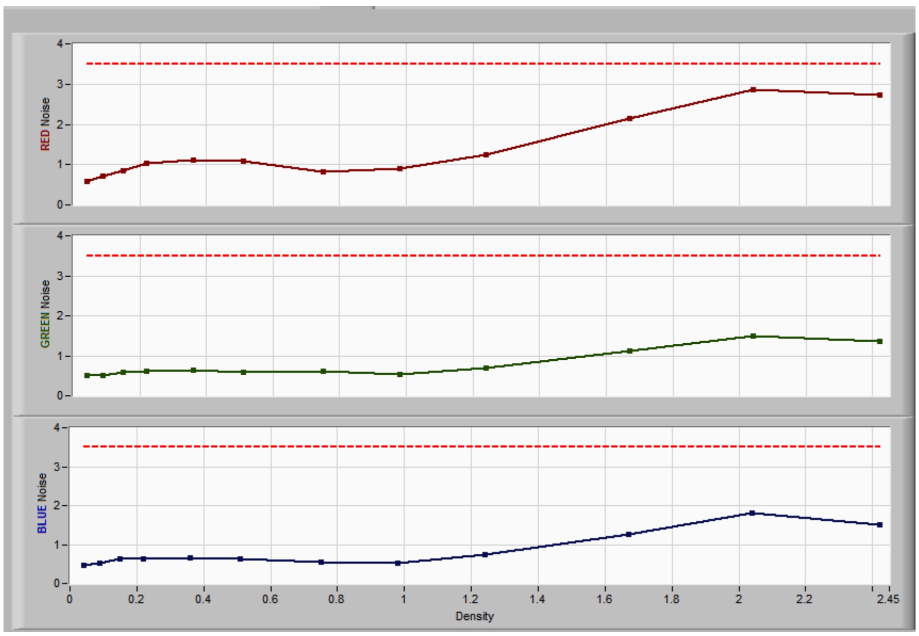


Fig. 8 – Noise level measurements showing 3 star threshold level

Color Misregistration

Whenever individual color channels in a displayed image are not spatially aligned or in register with each other **color misregistration** occurs. Often, this misregistration is a problem in the corners of the field of view where a lens' optical design is stressed. Another name for color misregistration is lateral color error. It manifests itself upon display as a colored fringing along edge transitions.

Color misregistration can be measured anywhere a slanted edge feature is used for the SFR calculation. The guideline performance levels for it in Table 8 allow for two different options. Option A is a single value specification that applies to any location within the field of view. If any single feature fails, the entire image fails. Option B provides for an average performance over the entire image with a not-to-exceed cap on any single edge feature. The user may select any option they wish.

Color Channel Mis-Registration				
Performance Level	AIM	TOLERANCE - select option A or B (applies to any FOV size)		
		A) Device or Object Targets (any single feature)	B) Device target only (averaged result)	
			max	avg.
★★★★	0	< 0.33 pixel	< 0.50 pixel	< 0.10 pixel
★★★	0	< 0.50 pixel	< 0.70 pixel	< 0.33 pixel
★★	0	< 0.80 pixel	< 0.90 pixel	< 0.50 pixel
★	0	> 0.80 pixel	> 0.90 pixel	> 0.50 pixel

Table 8 – Suggested Color Misregistration performance guidelines

The levels of Table 8 apply equally to the horizontal and vertical misregistration components as well as to red-green and blue –green errors. Fig. 9 illustrates a typical color misregistration report for all of these variables. In this example, a 4-star performance level is achieved for both options A and B.

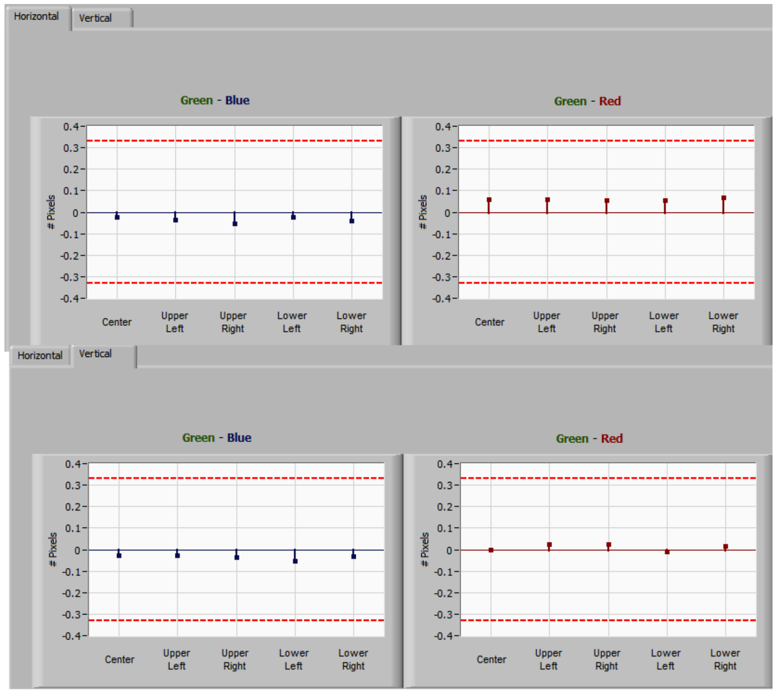


Fig. 9 – Sample Color misregistration error report: Performance level 4

Sampling Frequency

The number of pixels divided by a known distance on the object is very simply the **sampling frequency** associated with a digital image file. It is often measured in pixels per inch (ppi) or also dots per inch (dpi). It should not be confused with true optical resolution as covered under the SFR section.

Explicitly knowing the sampling frequency of an image file is important because it literally dictates what the physical size of the captured object is. Therefore any errors associated with it will cause the user to misinterpret the size of the original object.

Table 9 below provides the suggested error tolerances on the sampling frequency for any digitized object.

Sampling Frequency		
Performance Level	AIM	TOLERANCE
★★★★	user selected (e.g., 300, 400, 600 dpi)	+/- 1.00% of AIM
★★★		+/- 2.00% of AIM
★★		+/- 3.00% of AIM
★		> +/- 3.00% of AIM

Table 9 – Sampling Frequency error tolerance performance levels

The aim values are variable and user selected based on the level of information required. The tolerance levels are based on a percentage of these aims. Figure 10 below shows the reporting of the actual sampling frequency level in the SFR reporting panel.

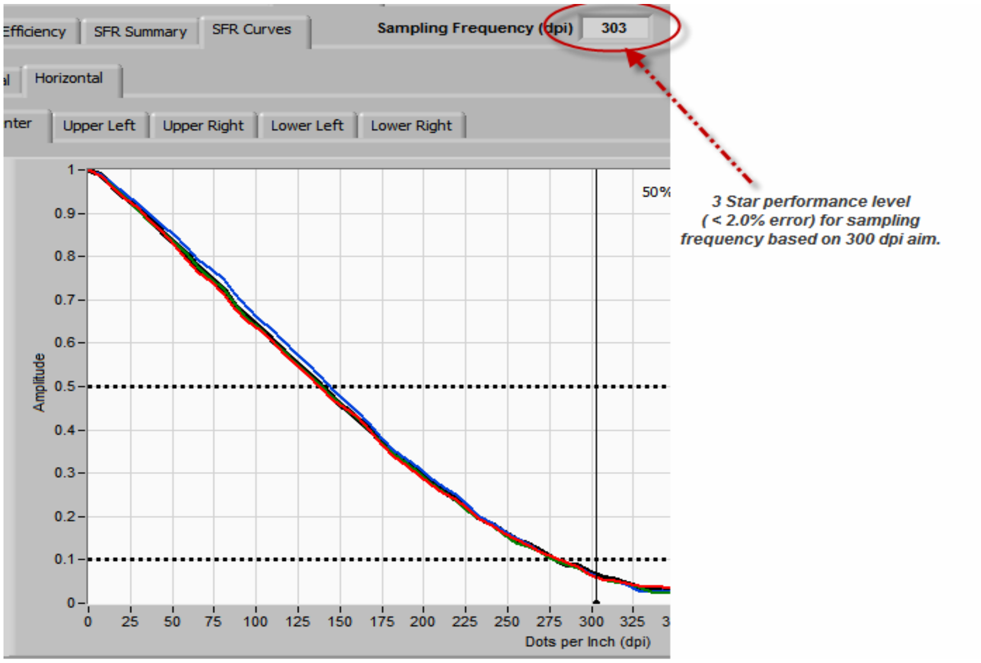


Fig. 10 – Example sampling frequency reporting for a digital image file

** for more definitions related to digitization (still image and AV), go to the Federal Agencies Digitization Guidelines [Glossary of Terms](#)s.*

How to Use the Tables for Objective Image Performance Criteria

The following are individual measurement criteria that provide the aim point and tolerances for imaging specifications based on a four-tiered performance model. These performance levels can be variably combined with respect to content type and imaging objectives. For instance, a sample specification is shown in Table 1. On the left is the metric name followed on the right by a 1 to 4-star specification code. In italics to the right is a description of the code. The performance level is largely driven by the TOLERANCE (i.e. allowable variability about the AIM). The tighter the tolerance level, the better the performance, and generally, the higher the cost.

Under the Still Image Working Group, there is a Categories and Objectives sub-group. This sub-group is in the process of developing a matrix that will map to the very type of multi-tier model used in the Quantitative Performance Guidelines. The work of this sub- group can be viewed here - http://digitizationguidelines.gov/stillimages/subcommittees.html

This imaging performance guideline model allows for real-world projects where a strict tolerance in one metric does not necessitate strict tolerances across the board. Referencing the system used in this table, a project may require a minimum four-star performance level for **color encoding**, but may only require a two-star performance level for **illuminance non-uniformity**. The acceptable tolerances are driven by both the physical characteristics of the content being imaged and the objectives of the imaging.

Two of the listed metrics include notes describing advances we expect to put forth in these areas. But rather than delay this guideline, we've included what we consider to be acceptable measures while outlining the advances we expect to develop for future versions.

Digital Imaging – Objective Performance Guidelines

The listed objective performance guidelines are intended to be a flexible tool for a variety of digital imaging projects. Each measure has associated aim points and tolerances, which are ranked using a four-star system related to level of performance. While some projects may justify highly critical performance aims and tolerances across all objective measures, many will have a mix of performance requirements.

Imaging performance is generally related to direct cost of service or equipment, or time for in-house imaging operations. As in any business operation, there are generally compromises to weigh in digital imaging. It is important to define your use cases in advance to identify the most critical needs based on the content and the objectives driving a project of program.

These guidelines can be applied equally to digital imaging projects or to digital imaging equipment, both to establish initial requirements as well as track quality.

Performance Rating			
*	**	***	****
◄— Less Critical		-	More Critical —►

Sampling Frequency		
PERFORMANCE LEVEL	AIM	TOLERANCE
****	User selected (e.g., 300, 400, 600 dpi)	+/- 0.50% of AIM
***		+/- 0.75% of AIM
**		+/- 1.5% of AIM
*		+/- 2.5% of AIM

Resolution - Spatial Frequency Response (SFR) High Frequency *(note 1)* (native response, no sharpening)			
PERFORMANCE LEVEL	AIM	TOLERANCE (for both horizontal and vertical directions equally)	
		Lower Limit sampling efficiency (luminance)	Upper Limit SFR response at half sampling frequency
****	100% Efficiency and 10% SFR	> 95%	< 0.20
***		> 90%	< 0.30
**		> 80%	< 0.40
*		< 80%	> 0.40

Resolution - Spatial Frequency Response (SFR) Mid-frequency *(note 1)* (native response, no sharpening)			
PERFORMANCE LEVEL	AIM	TOLERANCE (specified at half of selected dpi level or 50% the half-sampling frequency)	
		Lower Limit	Upper Limit
****	55% SFR	> 0.45	< 0.65
***		> 0.35	< 0.75
**		> 0.25	< 0.85
*		< 0.25	> 0.80

Note 1 – A more unified approach to aims and tolerances for resolution is currently being investigated by specifying the full SFR behavior. While it is recognized that resolution (illustrated here) is a single point summary measure from SFR, it is also accepted that more study and agreement is required before introducing full SFR guidelines, especially with respect to sharpening operators. Just as tone response specification moved from single patch metrics to a full OECF description, similarly single point resolution metrics will move to full SFR specification descriptor. Robust software tools and reporting methods also need to be developed before this can occur.

Sharpening – Single SFR Point *(Note 1a)*		
PERFORMANCE LEVEL	AIM	TOLERANCE Upper limit - any frequency between zero and half sampling values for the Luminance channel
****	N/A	< 1.0
***		< 1.1
**		< 1.2
*		> 1.2

Note 1a **-** It is recognized that sharpening processing is often applied to delivered image files and when used in moderation is acceptable. The specification cited here is meant to limit aggressive image sharpening that often creates haloing artifacts and unnatural appearing images. This specification should only be used when sharpening operations are unavoidable or agreed upon by client and vendor. In the future this specification will be provided by means of a full SFR function limits indicated in **note 1**.

Illuminance Non-uniformity		
PERFORMANCE LEVEL	AIM	TOLERANCE
****	0	< 1%
***	0	< 3%
**	0	< 5%
*	0	> 5%

Color Channel Misregistration				
PERFORMANCE LEVEL	AIM	TOLERANCE Select option A or B (applies to any FOV size)		
		A - Device or Object Targets (any single feature)	B - Device target only (averaged result)	
			max	mean
****	0	< 0.33	< 0.50 pixel	< 0.10 pixel
***	0	< 0.50	< 0.70 pixel	< 0.33 pixel
**	0	< 0.80	< 0.90 pixel	< 0.50 pixel
*	0	> 0.80	> 0.50 pixel	> 0.50 pixel

Tone Response (OECF)		
PERFORMANCE LEVEL	AIM	TOLERANCE - 8-bit equivalent (applies to all density levels & color channels)
****	Consistent with chosen color space (e.g. ECI, γ = 1.8 or 2.2) or user defined	± 3 count levels
***		± 6 count levels
**		± 9 count levels
*		> 9 count levels, < -9 count levels

White Balance Error		
PERFORMANCE LEVEL	AIM	TOLERANCE - 8-bit equivalent (applies to G-B, G-R difference for all neutral density levels)
****	0	± 3 count levels
***	0	± 4 count levels
**	0	± 6 count levels
*	0	± 8 count levels

Total Noise *(Note 2)*		
PERFORMANCE LEVEL	AIM	TOLERANCE - 8-bit equivalent (applies to Red, Green and Blue, and all neutral patches)
****	0.5	< 2.5 count levels (rms)
***	0.5	< 4.0 count levels (rms)
**	0.5	< 6.0 count levels (rms)
*	0.5	> 6.0 count levels (rms)

Note 2 – In the future this section may be complimented or replaced with a signal-to-noise (SNR) section. In theory, SNR is a superior and more resilient method for specifying the effects of noise on imaging performance. In practice though, challenges remain on the durability of measuring SNR in everyday scanning workflow environments. In short, the tools and experiences for measuring SNR in field conditions are immature at this time.

Color Encoding Error (Delta E 2000)					
PERFORMANCE LEVEL	AIM	TOLERANCE Select option A or B			
		A - ΔE (L*a*b*)		B - ΔE (*a*b*)	
		max	mean	max	mean
****	0	< 6	< 3	< 3	< 2
***	0	< 10	< 5	< 5	< 3
**	0	< 15	< 10	< 8	< 6
*	0	> 15	> 10	> 8	> 6

Other Artifacts or Imaging Problems

- Note any other problems that are identified while performing all the above assessments.
  - Examples – streaking in blue channel, blur in fast direction.
  - Unusual noise or grain patterns that vary spatially across the field.
  - One dimensional streaks and single or clustered pixel dropouts – sometimes these are best detected by visual inspection of individual color channels.
  - Color misregistration that changes with position – this is frequently observed along high contrast slant edges.

Reference Targets

We recommend including reference targets in each image of originals being scanned, including, at a minimum, a photographic gray scale as a tone and color reference and an accurate dimensional scale. If a target is included in each image, you may want to 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.

In a high production environment, it may be more efficient to scan targets separately and do it once for each batch of originals. The one target per batch approach is acceptable as long as all settings and operation of the equipment remains consistent for the entire batch and any image processing is applied consistently to all the images. For scanners and digital cameras that have an "auto range" function, the single target per batch approach may not work because the tone and color settings will be vary due to the auto range function, depending on the density and color of each original.

All targets should be positioned 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, this 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). Smaller versions of targets can be created by cutting down the full-size targets. Do not make the tone and color targets so small that it is difficult to see and use the target during scanning (this is particularly important when viewing and working with low resolution image previews within scanning software).

Make sure 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.

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.

All types of tone and color targets will probably need to be replaced on a routine basis. As the targets are used they will accumulate dirt, scratches, and other surface marks that reduce their usability. It is best to replace the targets sooner, rather than using old targets for a longer period of time.

For practical target-based quality management, multi-featured targets are preferable to those that can only provide a single performance metric (e.g., resolution, noise, or Delta E). Multi-featured image targets allow for the evaluation of common objective performance measures with a single scan or image capture. It is important for any image target to use ISO-compliant features and allow for standards-compliant evaluation and analysis – preferably with integrated or off-the-shelf software applications. Many such targets are currently available, including those available from Universal Test Target, Image Science Associates, and Imatest. Single- and multi-featured targets are available from other sources as well.

Targets – Device-level and Object-level

The following targets have been developed for the FADGI Still Image Working Group, and are capable of providing the reference, or ground-truth data for all the performance measure described above. Two targets have been developed for measuring image performance. The Device target (Figure 1) is designed for benchmarking of imaging devices as well as to validate requirements for a project or class of content being digitized. This target is imaged on a regular basis for cameras and scanners, but the target is not imaged along with the actual content.

The Image target (Figure 2) is designed to be imaged along side (top, bottom, or either side) the object being digitized. The inclusion of the image target with the item results is a self-describing image file with regard to image performance. Both targets are shown below with a description of the target features on the Device target. Object target shown as it is intended to be used. In this case, above a hand-colored albumen print.

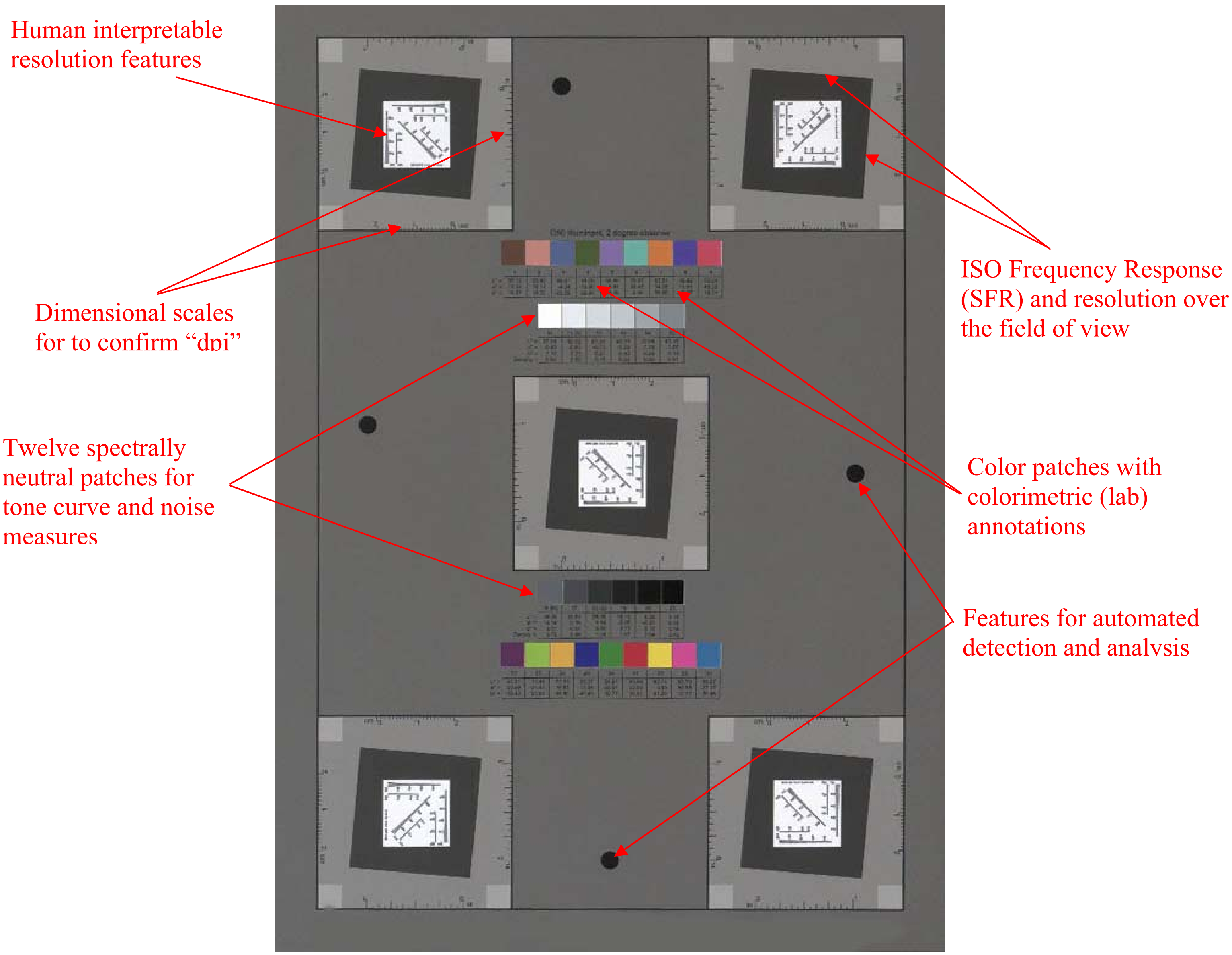


Figure 1 – Device Target

Figure 2 – Object target imaged with albumen print (artist unknown)

Scale and Dimensional References

Use an accurate dimensional scale as a reference for the size of original documents.

For reflection scanning, scales printed on photographic paper are very practical given the thinness of the paper and the dimensional accuracy that can be achieved during printing. Consider purchasing IEEE Std 167A-1995 facsimile test targets and using the ruler portion of the target along the left-hand edge. Due to the relatively small platen size of most scanners, you may need to trim the ruler off the rest of the target. Different length scales can be created to match the size of various originals. The Kodak Q-13 (8” long) or Q-14 (14” long) color bars have a ruler along the top edge and can be used as a dimensional reference; however, while these are commonly used, they are not very accurate.

For transmission scanning, consider using thin, clear plastic drafting scales/rulers. If these are too thick, create a ruler in a drafting/drawing application (black lines only on a white background) and print the ruler onto overhead transparency film on a laser printer using the highest possible resolution setting of the printer (600 ppi minimum). Compare printed scales to an accurate engineering ruler or tape measure to verify accuracy prior to using as a target. Again, different length scales can be created to match the size of various originals.

Targets for Tone and Color Reproduction

Reference targets can be used to assist with adjusting scanners and image files to achieve objectively “good images” in terms of tone and color reproduction. This is particularly true with reflection scanning. Copy negatives and copy transparencies should be produced with targets, gray scales and color bars, so they can be printed or scanned to match the original. Unfortunately, scanning original negatives is much more subjective, and this is also the case for copy negatives and copy transparencies that do not contain targets.

Reflection Scanning

We recommend including a Kodak Q-13 (8” long) or Q-14 (14” long) Gray Scale (20 steps, 0.10 density increments, and density range from approximately 0.05 to 1.95) within the area scanned. The Kodak gray scales are made of black-and-white photographic paper and have proven to work well as a reference target, including:

- Good consistency from gray scale to gray scale
- Good color neutrality
- Reasonably high visual density of approximately 1.95
- Provide the ability to quantify color and tone for the full range of values from black-point up to white-point
- The spectral response of the photographic paper has been a reasonable match for a wide variety of originals being scanned on a wide variety of scanners/digital cameras, few problems with metamerism
- The semi-matte surface tends to minimize problems with reflections and is less susceptible to scratching

The Kodak Color Control Patches (commonly referred to as color bars) from the Q-13 and Q-14 should only be used as a supplement to the gray scale, and never as the only target. The color bars are produced on a printing press and are not consistent. Also, the color bars do not provide the ability to assess color and tone reproduction for the full range of values from black-point to white-point.

Other gray scales produced on black-and-white photographic papers could be used. However, many have a glossy surface that will tend to scratch easily and cause more problems with reflections. Also, while being monochrome, some gray scales are not neutral enough to be used as a target.

IT8 color input targets (ex. Kodak Q-60) should not be used as scanning reference targets. IT8 targets are used for producing custom color profiles for scanning specific photographic papers, and therefore are produced on modern color photographic paper. Often, the neutral patches on IT8 targets are not neutral and the spectral response of the color photographic paper is not likely to match the response of most materials being scanned, therefore IT8 targets will not work well as a scanning reference. Also, there is little consistency from one IT8 target to another, even when printed on the same color photo paper.

Consider using a calibrated densitometer or colorimeter to measure the actual visual density or L*A*B* values of each step of the gray scales used as reference targets. Then use a laser printer to print the actual densities and/or

L*A*B* values (small font, white text on a gray background) and tape the information above the gray scale so the corresponding values are above each step; for the Kodak gray scales you may need to reprint the identifying numbers and letters for each step. This provides a quick visual reference within the digital image to the actual densities.

Transmission Scanning – Positives

Generally, when scanning transmissive positives, such as original color transparencies and color slides, a tone and color reference target is usually not necessary. Most scanners are reasonably well calibrated for scanning color transparencies and slides (usually they are not so well calibrated for scanning negatives).

Transparencies and slides have the highest density range of photographic materials routinely scanned. You may need to include within the scan area both a maximum density area of the transparency (typically an unexposed border) and a portion of empty platen to ensure proper auto ranging. Mounted slides can present problems, it is easy to include a portion of the mount as a maximum density area, but since it may not be easy to include a clear area in the scan, you should check highlight levels in the digital image to ensure no detail was clipped.

Ideally, copy transparencies and slides were produced with a gray scale and color bars in the image along with the original. The gray scale in the image should be used for making tone and color adjustments. Be sure to carefully evaluate the image using the gray scales in copy transparencies and slides to make sure that the illumination was even, that there are no reflections on the gray scale, and that the film was properly processed with no color crossovers (the highlights and shadows have very different color casts). If any problems exist, you may have problems using the gray scale in the image, as tone and color adjustments will have to be done without relying on the gray scale.

For the best results with transmission scanning, it is necessary to control extraneous light known as flare. It may be necessary to mask the scanner platen or light box down to the just the area of the item being scanned or digitized.

Generally, photographic step tablets on black-and-white film (see discussion on scanning negatives below) are not good as tone and color reference targets for color scanning.

Transmission Scanning – Negatives

We recommend including an uncalibrated Kodak Photographic Step Tablet (21 steps, 0.15 density increments, and density range of approximately 0.05 to 3.05), No. 2 (5” long) or No. 3 (10” long), within the scan area. The standard density range of a step tablet exceeds the density range of most originals that would be scanned, and the scanner can auto-range on the step tablet minimizing loss of detail in the highlight and/or shadow areas of the image.

For master image files, we recommend the brightness range be optimized or matched to the density range of the originals. It may be necessary to have several step tablets, each with a different density range to approximately match the density range of the items being scanned; it is preferable the density range of the step tablet just exceeds the density range of the original. These adjusted step tablets can be produced by cutting off the higher density steps of standard step tablets. If originals have a very short or limited density range compared to the reference targets, this may result in quantization errors or unwanted posterization effects when the brightness range of the digital image is adjusted; this is particularly true for images from low-bit or 8-bit per channel scanners compared to high-bit scanners/cameras.

Ideally, copy negatives were produced with a gray scale and/or color bars in the image along with the original. The gray scale in the image should be used for making tone and/or color adjustments. Be sure to carefully evaluate the image using the gray scales in copy negatives to make sure that the illumination was even, that there are no reflections on the gray scale, and for color film, that the film was properly processed with no color crossovers (the highlights and shadows have very different color casts). If any problems exist with the quality of the copy negatives, you may have problems using the gray scale in the image, as tone and/or color adjustments will have to be done without relying on the gray scale.

For the best results with transmission scanning, it is necessary to control extraneous light known as flare. It may be necessary to mask the scanner platen or light box down to the just the area of the item being scanned or digitized. This is also true for step tablets being scanned as reference targets. Also, due to the progressive nature of the step tablet, with the densities increasing along the length, it may be desirable to cut the step tablet into shorter sections and mount them out of sequence in an opaque mask; this will minimize flare from the low density areas influencing the high density areas.

Consider using a calibrated densitometer to measure the actual visual and color density of each step of the step tablets used as reference targets. Use a laser printer to print the density values as gray letters against a black background and print onto overhead transparency film, size and space the characters to fit adjacent to the step tablet. Consider mounting the step tablet (or a smaller portion of the step tablet) into an opaque mask with the printed density values aligned with the corresponding steps. This provides a quick visual reference within the digital image to the actual densities.

III. IMAGING WORKFLOW

Adjusting Image Files

There is a common misconception that image files saved directly from a scanner or digital camera are pristine or unmolested in terms of the image processing. For almost all image files this is simply untrue. Only “raw” files from scanners or digital cameras are unadjusted, all other 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.

Because of this misconception, many people argue you 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 you require. 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.

Also, some people suggest it is best to save raw image files, because no “bad” image processing has been applied. This assumes you can do a better job adjusting for the deficiencies of a scanner or digital camera than the manufacturer, and that you have 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.

We believe 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.

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 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:

  . i. Reasonably accurate in terms of tone and color reproduction, if possible without relying on color management.

  . ii. Consistent in terms of tone and color reproduction, both image to image consistency and batch-to-batch consistency.

  . iii. 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:

. i. If needed 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.

. ii. 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:

. i. Achieve final color balance and eliminate color biases (color images).

. ii. Achieve desired tone distribution (grayscale and color images).

. iii. Sharpen images to match appearance of the originals, 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).

Scanning Aimpoints

One approach for ensuring accurate tone reproduction (the appropriate distribution of the tones) for digital images is to place selected densities on a gray scale reference target at specific digital levels or aimpoints. Also, for color images it is possible to improve overall color accuracy of the image by neutralizing or eliminating color biases of the same steps of the gray scale used for the tone reproduction aimpoints.

This approach is based on working in a gray-balanced color space, independent of whether it is an ICC color managed workflow or not.

In a digital image, the white point is the lightest spot (highest RGB levels for color files and lowest % black for grayscale files) within the image, the black point is the darkest spot (lowest RGB levels for color files and highest% black for grayscale files), and a mid-point refers to a spot with RGB levels or % black in the middle of the range.

Generally, but not always, the three aimpoints correspond to the white-point, a mid-point, and the black-point within a digital image, and they correspond to the lightest patch, a mid-density patch, and the darkest patch on the reference gray scale within the digital image. This assumes the photographic gray scale has a larger density range than the original being scanned. In addition to adjusting the distribution of the tones, the three aimpoints can be used for a three point neutralization of the image to eliminate color biases in the white-point, a mid-point, and the black-point.

The aimpoints cited in this section are guidelines only. Often it is necessary to vary from the guidelines and use different values to prevent clipping of image detail or to provide accurate tone and color reproduction.

The above images illustrate the importance of controlling the image tones so detail or information is not clipped or lost. The top images have been carefully adjusted using aimpoints and a reference target so all image detail is visible and distinct. The bottom images have been adjusted so the highlight detail in the photograph on the left and the light shades (for the Red channel) in the document on the right have been clipped or rendered at the maximum brightness value (measured as percent gray for the grayscale image and RGB levels for the color image). Clipping or loss of image detail can happen in the shadow detail or dark shades as well, with the pixels being rendered at the lowest brightness value or black. The loss of detail and texture is obvious in the magnified close-up details. Looking at the overall images, the difference in appearance is subtle, but the loss of information is apparent. [photograph on left- President Harry S. Truman, 7/3/1947, NARA– Harry S. Truman Library; document on right- 11th Amendment, RG 11 General Records of the United States Government, NARA Old Military and Civil LICON]

Since the aimpoints rely on a photographic gray scale target, they are only applicable when a gray scale is used as a reference. If no gray scale is available (either scanned with the original or in a copy transparency/negative), the Kodak Color Control Patches (color bars) can be used and alternative aimpoints for the color bars are provided. We recommend using a photographic gray scale and not relying on the color bars as the sole target.

Many image processing applications have automatic and manual "place white-point" and "place black-point" controls that adjust the selected areas to be the lightest and darkest portions of the image, and that will neutralize the color in these areas as well as. Also, most have a "neutralize mid-point" control, but usually the tonal adjustment for brightness has to be done separately with a "curves", "levels", "tone curve", etc, control. The better applications will let you set the specific RGB or % black levels for the default operation of the place white-point, place black-point, and neutralize mid-point controls.

Typically, both the brightness placement (for tone reproduction) and color neutralization to adjust the color balance (for color reproduction) should be done in the scanning step and/or as a post-scan adjustment using image processing software. A typical manual workflow in Adobe Photoshop is black-point placement and neutralization (done as a single step, control set to desired neutral level prior to use), white-point placement and neutralization (done as a single step, control set to desired neutral level prior to use), mid-point neutralization (control set to neutral value prior to use), and a gamma correction to adjust the brightness of the mid point (using levels or curves). For grayscale images the mid-point neutralization step is not needed. The tools in scanner software and other image processing software should allow for a similar approach, the sequence of steps may need to be varied to achieve best results.

The three point tone adjustment and color neutralization approach does not guarantee accurate tone and color reproduction. It works best with most scanners with reflection scanning, but it can be difficult to achieve good tone and color balance when scanning copy negatives/transparencies. It can be very difficult to produce an accurate digital image reproduction from color copy negatives/transparencies that exhibit color crossover or other defects such as under/over exposure or a strong color cast. The three point neutralization approach will help minimize these biases, but may not eliminate the problems entirely.

If the overall color balance of an image is accurate, using the three point neutralization to adjust the color reproduction may cause the color balance of the shades lighter and darker than the mid-point to shift away from being neutral. For accurate color images that need to have just the tone distribution adjusted, apply levels or curves adjustments to the luminosity information only, otherwise the overall color balance is likely to shift.

When scanning photographic prints it is important to be careful about placing the black point, in some cases the print being scanned will have a higher density than the darkest step of the photographic gray scale. In these cases, you should use a lighter aimpoint for the darkest step of the gray scale so the darkest portion of the image area is placed at the normal aimpoint value (for RGB scans, the shadow area on the print may not be neutral in color and the darkest channel should be placed at the normal aimpoint).

Occasionally, objects being scanned may have a lighter value than the lightest step of the photographic gray scale, usually very bright modern office papers or modern photo papers with a bright-white base. In these cases, you should use a darker aimpoint for the lightest step of the gray scale so the lightest portion of the image area is placed at the normal aimpoint value (for RGB scans, the lightest area of the object being scanned may not be neutral in color and the lightest channel should be placed at the normal aimpoint).

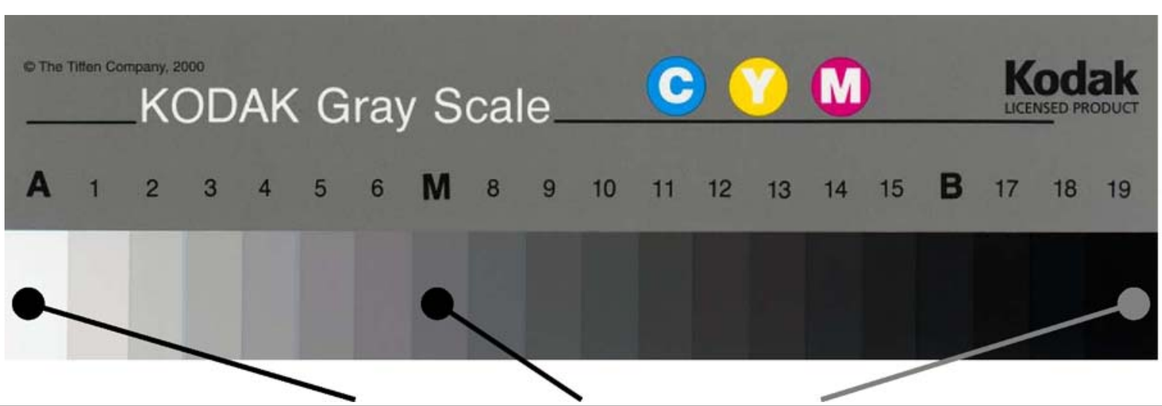
Aimpoints may need to be altered not only for original highlight or shadow values outside the range of the gray scale, but also deficiencies in lighting, especially when scanning photographic intermediates. Excessive flare, reflections, or uneven lighting may need to be accounted for by selecting an alternate value for a patch, or selecting a different patch altogether. At no point should any of the values in any of the color channels of the properly illuminated original fall outside the minimum or maximum values indicated below for scanning without a gray scale.

The following table provides aimpoints that are geared towards monitor display and also for printed output on a variety of printers. The aimpoints are based on recommendations made in both the 1998 and 2004 NARA *Technical Guidelines for Digitizing Archival Materials for Electronic Access.* Other institutions have developed similar approaches, but with slightly different aimpoint values, which may be designed more for pre-press work. For example, see the *Metamorfoze Preservation Imaging Guidelines* at http://www.metamorfoze.nl; GPO's *Specification and Operating Procedures for Quality Control: Creation of Preservation Master Files, Version 1.1* at http://www.gpoaccess.gov/legacy/specification-qc-v1-1.pdf; Columbia University's Imaging Standards and Procedures: Use of Targets at https://www1.columbia.edu/sec/cu/libraries/bts/imaging/lab/targets.html. Because the following aimpoints are geared towards monitor display, the blacks are darker and the lights are whiter than some of the aimpoints cited in the examples above.

The following table provides aimpoints with a slightly compressed tonal scale designed to minimize potential problems when printing the image files.

All aimpoint measurements and adjustments should be made using either a 5x5 pixel (25 pixels total) or 3x3 pixel (9 pixels total) sample. Avoid using a point-sample or single pixel measurement.

Aimpoints for Photographic Gray Scales -

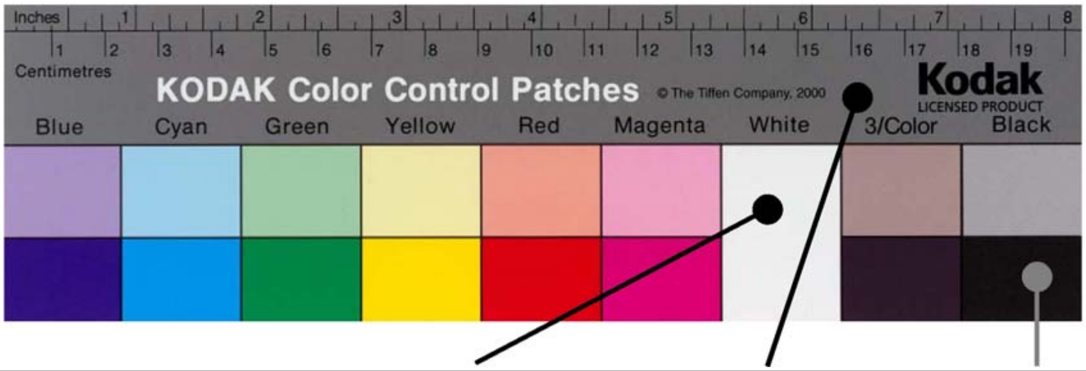


		Neutralized White Point	Neutralized Mid Point*	Neutralized Black Point	Alternative Neutralized Black Point**
Step or Density	Kodak Q-13/Q-14	A	M	19	B
	Visual Density	0.05 to 0.10	0.75 to 0.85	1.95 to 2.05	1.65 to 1.75
Aimpoint	RGB Levels	242-242-242	104-104-104	12-12-12	24-24-24
	% Black	5%	59%	95%	91%
Acceptable Range for Aimpoint	RGB Level	239 to 247	100 to 108	8 to 16	20 to 28
	% Black	3% to 6%	58% to 61%	94% to 97%	89% to 92%

*When using the recommended black point, step 19, the aimpoint for mid point (MP) to be calculated from actual values for white point (WP) and step 19 black point (BP) using the following formula: MP = WP – 0.60(WP – BP)

**Sometimes there may be problems when trying to use the darkest step of the gray scale - such as excessive flare, reflections, or uneven lighting - and it may be better to use the B-step as the black point. When using the alternative black point, B-step, the aimpoint for mid point (MP) to be calculated from actual values for white point (WP) and step B black point (BP) using the following formula: MP = WP – 0.63(WP – BP)

Alternative Aimpoints for Kodak Color Control Patches (color bars)



		Neutralized White Point	Neutralized Mid Point*	Neutralized Black Point
Color Patch/Area		White	Gray Background	Single Color Black
Aimpoint	RGB Levels	237-237-237	102-102-102	23-23-23
	% Black	7%	60%	91%
Acceptable Range for Aimpoint	RGB Level	233 to 241	98 to 106	19 to 27
	% Black	5% to 9%	58% to 62%	89% to 93%

*Aimpoint for mid point (MP) to be calculated from actual values for white point (WP) and black point (BP) using the following formula: MP = WP – 0.63(WP – BP)

Aimpoint Variability

For the three points that have been neutralized and placed at the aimpoint values: no more than +/- 3 RGB level variance from aimpoints and no more than 3 RGB level difference in the individual channels within a patch for RGB scanning and no more than +/- 1% level variance from the aimpoints in % black for grayscale scanning. Again, the image sampler (in Adobe Photoshop or other image processing software) should be set to measure an average of either 5x5 pixels or 3x3 pixels when making these measurements, point sample or single pixel measurements should not be used.

Other steps on the gray scale may, and often will, exhibit a higher degree of variation. Scanner calibration, approaches to scanning/image processing workflow, color management, and variation in the target itself can all influence the variability of the other steps and should be used/configured to minimize the variability for the other steps of the gray scale. Usually the other steps of the gray scale will be relatively consistent for reflection scanning, and significantly less consistent when scanning copy negatives and copy transparencies.

Minimum and Maximum Levels

The minimum and maximum RGB or % black levels when scanning materials with no reference gray scale or color patches, such as original photographic negatives:

- For RGB scanning the highlight not to go above RGB levels of 247 - 247 - 247 and shadow not to go below RGB levels of 8 - 8 - 8.
- For grayscale scanning the highlight not to go below % black of 3 % and shadow not to go above % black of 97%.

Color Management Background:

Digitization is the conversion of analog color and brightness values to discrete numeric values. A number, or set of numbers, designates the color and brightness of each pixel in a raster image. The rendering of these numerical values, however, is very dependent on the device used for capture, display or printing. Color management provides a context for objective interpretation of these numeric values, and helps to compensate for differences between devices in their ability to render or display these values, within the many limitations inherent in the reproduction of color and tone.

Color management does not guarantee the accuracy of tone and color reproduction. We recommend color management not be used to compensate for poor imaging and/or improper device calibration. As described above, it is most suitable to correct for color rendering differences from device to device.

Every effort should be made to calibrate imaging devices and to adjust scanner/digital camera controls to produce the most accurate images possible in regard to tone and color reproduction (there are techniques for rescuing poorly captured images that make use of profile selection, particularly synthesized profiles, that will not be discussed here. For further information see the writings of Dan Margulis and Michael Kieran). Calibration will not only improve accuracy of capture, but will also ensure the consistency required for color management systems to function by bringing a device to a stable, optimal state. Methods for calibrating hardware vary from device to device, and are beyond the scope of this guidance.

International Color Consortium (ICC) Color Management System

Currently, ICC-based color management is the most widely implemented approach. It 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. The PCS will not be discussed further.
- 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.
- Rendering intent
  - Rendering intents determine how out-of-gamut colors will be treated in color space transformations.
- CMM (Color Management Module)
  - The CMM performs the calculations that transform color descriptions between color spaces.

Profiles

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 PCS.

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 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, while not wasting bits on unnecessary color descriptions. 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 color space profile adequately meets these criteria and is recommended for storing RGB image files. Adobe RGB 1998 has a reasonably large color gamut, sufficient for most purposes when saving files as 24-bit RGB files (low-bit files or 8-bits per channel). Using larger gamut color spaces with low-bit files can cause quantization errors, therefore wide gamut color spaces are more appropriate when saving high-bit or 48-bit RGB files. Gray Gamma 2.2 (available in Adobe products) is recommended for grayscale images.

An ideal workflow would be to scan originals with a calibrated and characterized device, assign the profile of that device to the image file, and convert the file to the chosen workspace (Adobe RGB 1998 for color or Gray Gamma 2.2 for grayscale). Not all hardware and software combinations produce the same color and tonal conversion, and even this workflow will not always produce the best results possible for a particular device or original. Different scanning, image processing and printing applications have their own interpretation of the ICC color management system, and have varying controls that produce different levels of quality. It may be necessary to deviate from the normal, simple color managed workflow to achieve the best results. There are many options possible to achieve the desired results, many of which are not discussed here because they depend on the hardware and software available.

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. Of the four, perceptual and relative colorimetric intents are most appropriate for creation of master files and their derivatives. In general, we have found that perceptual intent works best for photographic images, while relative colorimetric works best for images of text documents and graphic originals. It may be necessary to try both rendering intents to determine which will work best for a specific image or group of images.

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 are 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 colorimetric intent usually works best.

Color Management Modules

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 superceded by choosing a CMM in the image processing application at the time of conversion. We recommend that you choose a CMM that produces acceptable results for project-specific imaging requirements, and switch only when unexpected transformations occur.

Image Processing

After capture and transformation into one of the recommended color spaces (referred to as a "working space" at this point in the digitization process), most images require at least some image processing to produce the best digital rendition of the original. The most significant adjustments are color correction, tonal adjustment, and sharpening. These processes involve data loss and should be undertaken carefully since they are irreversible once the file is saved. Images should initially be captured as accurately as possible; image processing should be reserved for optimizing an image, rather than for overcoming poor imaging.

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.

- 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.).

Sharpening

Digitization utilizes optics in the capture process and the sharpness of different imaging systems varies. Most scans will require some amount of sharpening to reproduce the apparent sharpness of the original. Generally, the higher the spatial resolution, the less sharpening that will be needed. As the spatial resolution reaches a level that renders fine image detail, such as image grain in a photograph, the large features of an image will appear sharp and will not require additional sharpening. Conversely, lower resolution images will almost always need some level of sharpening to match the appearance of the original.

Sharpening tools available from manufacturers use different controls, but all are based on increasing contrast on either side of a defined brightness difference in one or more channels. Sharpening exaggerates the brightness relationship between neighboring pixels with different values, and this process improves the perception of sharpness.

Sharpening of the production master image files should be done conservatively and judiciously; generally it is better to under-sharpen than to over-sharpen. Over-sharpening is irreversible and should be avoided, but it is not objectively measurable. Often over-sharpening will appear as a lighter halo between areas of light and dark.

We recommend using unsharp mask algorithms, rather than other sharpening tools, because they provide the best visual results and usually give greater control over the sharpening parameters. Also:

- Sharpening must be evaluated at an appropriate magnification (1:1 or 100%) and the amount of sharpening is contingent on image pixel dimensions and subject matter.
- Sharpening settings for one image or magnification may be inappropriate for another.
- In order to avoid color artifacts, or fringing, appropriate options or techniques should be used to limit sharpening only to the combined channel brightness.
- The appropriate amount of sharpening will vary depending on the original, the scanner/digital camera used, and the control settings used during digitization.

Sample Image Processing Workflow:

The following provides a general approach to image processing 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. You can 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 your computer 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.

The post-scan sequence is based on using Adobe Photoshop software.

Scanning

Adjust size, scaling, and spatial resolution.

Color correction and tone adjustment-

- Follow 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.

Saturation adjustment for color scans.

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 accuracy of 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 desired color space or convert from scanner space; use 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 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 (levels recommended, curves alternative) to place and neutralize the black-point, place and neutralize the white-point, and to neutralize mid-point. When color correcting photographic images, levels and curves may both be used.
- Alternative – try auto-correct function within levels and curves (adjust options, including algorithm, targets, and clipping) and assess results. If auto-correct does a reasonable job, then use manual controls for minor adjustments.
- Alternative – if only global controls are available, adjust overall color balance.

Tone adjustment, for color files apply correction to luminosity information only

- Recommended – use precision controls (levels recommended, curves alternative) to adjust all three aimpoints in iterative process - 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.
- Alternative – try auto-correct function within levels and curves (adjust options, including algorithm, targets, and clipping) and assess results. If auto-correct does a reasonable job, then use manual controls for minor adjustments.
- Alternative – if only global controls are available, adjust contrast and brightness.

Crop and/or deskew.

Check image dimensions and resize.

Convert to 8-bits per channel – either 24-bit RGB or 8-bit grayscale.

Sharpen – Unsharp mask algorithm, applied to approximate appearance of original. For color files, apply unsharp mask to luminosity information only. Version CS of Photoshop has the ability to apply unsharp mask to luminosity in high-bit mode, in this case sharpening should be done prior to the final conversion to 8-bits per channel.

Manual clean up of dust and other artifacts, such as surface marks or dirt on copy negatives or transparencies, introduced during the scanning step. If clean up is done earlier in the image processing workflow prior to sharpening, it is a good idea to check a second time after sharpening since minor flaws will be more obvious after sharpening.

Save file.

Again, the actual image processing workflow will depend on the originals being digitized, the equipment and software being used, the desired image parameters, and the desired productivity. Adjust the image processing workflow for each specific digitization project.

IV. DIGITIZATION SPECIFICATIONS FOR RECORD TYPES

The intent of the following tables is to present recommendations for scanning a variety of original materials in a range of formats and sizes. The tables are broken down into six main categories: textual documents (including manuscripts, books, graphic illustrations/artworks, maps, plans, and oversized documents); reflective photographic formats (prints); transmissive photographic formats (negatives, slides, transparencies); reflective aerial photographic formats (prints); transmissive aerial photographic formats (negatives, positives); graphic materials (graphic illustrations, drawings, posters); and objects and artifacts.

Because there are far too many formats and document characteristics for comprehensive discussion in these guidelines, the tables below provide scanning recommendations for the most typical or common document types and photographic formats found in most cultural institutions. The table for textual documents is organized around physical characteristics of documents which influence capture decisions. The recommended scanning specifications for text support the production of a scan that can be reproduced as a legible facsimile at the same size as the original (at 1:1, the smallest significant character should be legible). For photographic materials, the tables are organized around a range of formats and sizes that influence capture decisions.

NOTE: We recommend digitizing to the original size of the records following the resolution requirements cited in the tables (i.e. no magnification, unless scanning from various intermediates). Be aware that many Windows applications will read the resolution of image files as 72 ppi by default and the image dimensions will be incorrect.

Workflow requirements, actual usage needs for the image files, and equipment limitations will all be influential factors for decisions regarding how records should be digitized. The recommendations cited in the following section and charts, may not always be appropriate. Again, the intent for these *Technical Guidelines* is to offer a range of options and actual approaches for digitizing records may need to be varied.

Cleanliness of Work Area, Digitization Equipment, and Originals

Keep work area clean. 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, NARA's *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 (just as is done in a traditional darkroom or for copy photography).

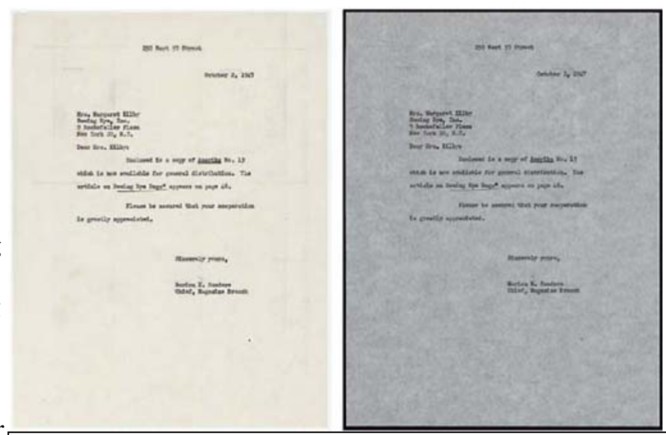
Cropping

We recommend the entire document be scanned, no cropping allowed. A small border should be visible around the entire document or photographic image. Careful placement of documents on flatbed scanners may require the originals to be away from platen edge to avoid cropping.

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. Otherwise, scan photographs so there is only a small border around just the image area.

Backing reflection originals

We recommend backing all originals with a bright white opaque paper (such as a smooth finish cover stock), occasionally, an off-white or cream-colored paper may complement the original document and should be used. For most documents, the bright white backing will provide a lighter shade for scanner auto-ranging and minimize clipping of detail in the paper of the original being scanned. In the graphic arts and photography fields, traditionally items being copied to produce line negatives (somewhat equivalent to 1-bit scanning) have been backed with black to minimize bleed-through from the back. However, this can create very low contrast and/or grayed-out digital images when the paper of the original document is not opaque and when scanning in 8-bit grayscale or 24-bit RGB color. Backing with white paper maximizes the paper brightness of originals and the white border around the originals is much less distracting.



The above document, a carbon copy on thin translucent paper, was scanned and backed with white paper on the left and with black paper on the right. Using a white backing enhances text contrast and allows the scanner to auto-range on the light background, this helps minimize clipping of the tones in the paper of the document. A black backing may minimize bleed-through of text from the back of the page (a technique that may only work well with 1-bit images), but will significantly lower the overall image contrast, gray-out the document image, and show significant paper texture.

Scanning Encapsulated or Sleeved Originals

Scanning/digitizing originals that have been encapsulated or sleeved in polyester film can present problems- the visual appearance is changed and the polyester film can cause Newton's rings and other interference patterns.

The polyester film changes the visual appearance of the originals, increasing the visual density. You can compensate for the increase by placing the tone and color reference target (photographic gray scale) into a polyester sleeve (this will increase the visual density of the reference target by the same amount) and scan using the normal aimpoints.

Interference patterns known as Newton's rings are common when two very smooth surfaces are placed in contact, such as placing encapsulated or sleeved documents onto the glass platen of a flatbed scanner; the susceptibility and severity of Newton's rings varies with the glass used, with coatings on the glass, and with humidity in the work area. These patterns will show up in the digital image as multi-colored concentric patterns of various shapes and sizes. Also, we have seen similar interference patterns when digitizing encapsulated documents on a digital copy stand using a scanning camera back, even when there is nothing in contact with the encapsulation. Given the complex nature of these interference patterns, it is not practical to scan and then try to clean-up the image. Some scanners use special glass, known as anti-Newton's ring glass, with a slightly wavy surface to prevent Newton's rings from forming.

To prevent interference patterns, use scanners that have anti-Newton's ring glass and avoid scanning documents in polyester film whenever practical and possible. Some originals may be too fragile to be handled directly and will have to be scanned in the polyester encapsulation or sleeve. One option is to photograph the encapsulated/sleeved document first and then scan the photographic intermediate; generally this approach works well, although we have seen examples of interference patterns on copy transparencies (to a much lesser degree compared to direct digitization).

Embossed seals

The close-up on the left shows an embossed seal when scanned on a flatbed scanner with two lights and very even illumination, while the close-up on the right shows the seal from the same document scanned on a flatbed scanner set to use one directional light.

Some documents have embossed seals, such as notarized documents, or wax seals that are an intrinsic legal aspect of the documents. Most scanners are designed with lighting to minimize the three dimensional aspects of the original documents being scanned, in order to emphasize the legibility of the text or writing. In most cases, embossed seals or the imprint on a wax seal will not be visible and/or legible in digital images from these scanners, and this raises questions about the authenticity of the digital representation of the documents. Some scanners have a more directed and/or angled lighting configuration that will do a better job reproducing embossed seals. With a few scanners, the operator has the control to turn off one light and scan using lighting from only one direction, this approach will work best for documents with embossed or wax seals. Similarly, when using a digital copy stand, the lighting can be set up for raking light from one direction (make sure the light is still even across the entire document). When working with unidirectional lighting, remember to orient the document so the shadows fall at the bottom of the embossment/seal and of the document.

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, you should run tests to determine there is sufficient improvement in the final image quality to justify the extra time and effort. Generally, we recommend over-scanning at 1.5 times the desired final resolution, as an example- 400 ppi final x 1.5 = 600 ppi scan resolution.

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.

The Quality Index (QI) measurement was designed for printed text where character height represents the measure of detail. Cornell University has developed a formula for QI based on translating the Quality Index method developed for preservation microfilming standards to the digital world. The QI formula for scanning text relates quality (QI) to character size (h) in mm and resolution (dpi). As in the preservation microfilming standard, the digital QI formula forecasts levels of image quality: barely legible (3.0), marginal (3.6), good (5.0), and excellent (8.0). However, manuscripts and other non-textual material representing distinct edge-based graphics, such as maps, sketches, and engravings, offer no equivalent fixed metric. For many such documents, a better representation of detail would be the width of the finest line, stroke, or marking that must be captured in the digital surrogate. To fully represent such a detail, at least 2 pixels should cover it. (From *Moving Theory into Practice: Digital Imaging for Libraries and Archives,* Anne R. Kenney and Oya Y. Rieger, editors and principal authors. Research Libraries Group, Mountain View, CA: 2000).

Optical character recognition, the process of converting a raster image of text into searchable ASCII data, is not addressed in this document. 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.

Scanning Oversized

Scanning oversized originals can produce very large file sizes. It is important to evaluate the need for legibility of small significant characters in comparison to the overall file size when determining the appropriate scanning resolution for oversized originals.

Scanning Photographs

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. At this time, we do not feel that there is a valid counterpart for photographic materials to the DLF benchmarks for preservation digitization of text materials.

The recommended scanning specifications for photographs support the capture of an appropriate level of detail from the format, and, in general, support the reproduction, at a minimum, of a high-quality 8"x10" print of the photograph. For photographic formats in particular, it is important to carefully analyze the material prior to scanning, especially if it is not a camera original format. 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.).

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.

Original photographic negatives are much more difficult to scan compared to positive originals (prints, transparencies, slides, etc.), with positives there is an obvious reference image that can be matched and for negatives there is not. When scanning negatives, for master files the tonal orientation should be inverted to produce a positive image. The resulting image will need to be adjusted to produce a visually pleasing representation. Digitizing negatives is very analogous to printing negatives in a darkroom and it is very dependent on the photographer's/ technician's skill and visual literacy to produce a good image. There are few objective metrics for evaluating the overall representation of digital images produced from negatives.

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 are very subject dependent, and images may or may not have a full tonal range.

Often it is better to scan negatives in positive mode (to produce an initial image that appears negative) because frequently scanners are not well calibrated for scanning negatives and detail is clipped in either the highlights and/or the shadows. After scanning, the image can be inverted to produce a positive image. Also, often it is better to scan older black-and-white negatives in color (to produce an initial RGB image) because negatives frequently have staining, discolored film base, retouching, intensification, or other discolorations (both intentional and the result of deterioration) that can be minimized by scanning in color and performing an appropriate conversion to grayscale. Evaluate each color channel individually to determine which channel minimizes the appearance of any deterioration and optimizes the monochrome image quality, and use that channel for the conversion to a grayscale image.

Scanning Intermediates

Adjust scaling and scan resolution to produce image files that are sized to the original document at the appropriate resolution, or matched to the required QI (legibility of the digital file may be limited due to loss of legibility during the photographic copying process) for text documents.

For copy negatives (B&W and color), if the copy negative has a Kodak gray scale in the image, adjust the scanner settings using the image of the gray scale to meet the above requirements. If there is no gray scale, the scanner software should be used to match the tonal scale of the digital image to the density range of the specific negative being scanned to provide an image adjusted for monitor representation.

For color copy transparencies and color microfilm, if the color intermediate has a Kodak gray scale in the image, adjust the scanner settings using the image of the gray scale to meet the above requirements. If there is no gray scale, the scanner software should be used to match the tonal scale and color balance of the digital image to the specific transparency being scanned to provide an accurate monitor representation of the image on the transparency.

There are more specific details regarding scanning photographic images from intermediates in the notes following the photo scanning tables.

Generally, for

- 35mm color copy slides or negatives, a 24-bit RGB digital file of approximately 20 MB would capture the limited information on the film for this small format.
- Approximate maximum scan sizes from color film, 24-bit RGB files (8-bit per channel):[1]

Original Color Film		Duplicate Color Film	
35mm	50 MB	35mm	17 MB
120 square	80 MB	120 square	27 MB
120 6x4.5	60 MB	120 6x4.5	20 MB
120 6x9	90 MB	120 6x9	30 MB
4x5	135 MB	4x5	45 MB
8x10	240 MB	8x10	80 MB

Scanning Microfilm

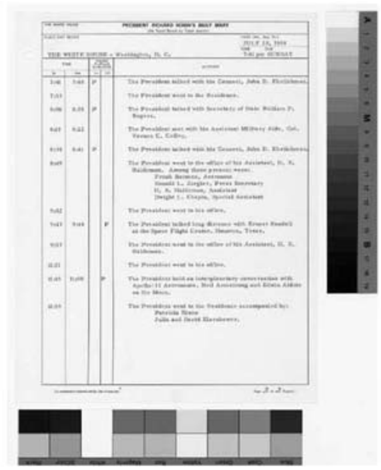
When scanning microfilm, often the desire is to produce images with legible text. Due to photographic limitations of microfilm and the variable quality of older microfilm, it may not be possible to produce what would normally be considered reproduction quality image files. Your scanning approach may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

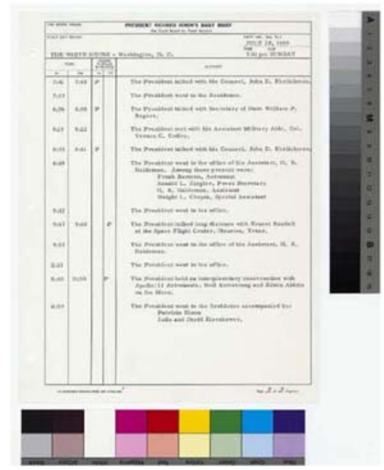
For B&W microfilm, scanner software should be used to match the tonal scale of the digital image to the density range of the specific negative or positive microfilm being scanned. Example: the minimum density of negative microfilm placed at a maximum % black value of 97% and the high density placed at a minimum % black value of 3%.

[1] From - Digital and Photographic Imaging Services Price Book, Rieger Communications Inc, Gaithersburg, MD, 2001- "In our opinion and experience, you will not achieve better results than can be obtained from the scan sizes listed. Due to the nature of pixel capture, scanning larger does make a difference if the scan is to be used in very high magnification enlargements. Scan size should not be allowed to fall below 100 DPI at final magnification for quality results in very large prints."

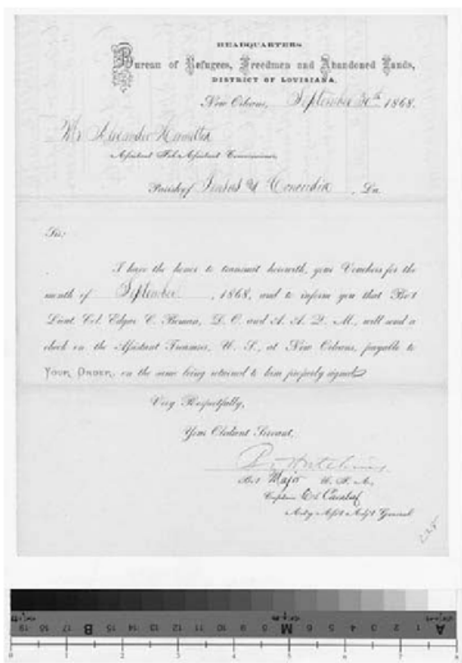
Illustrations of Record Types:

Textual Documents





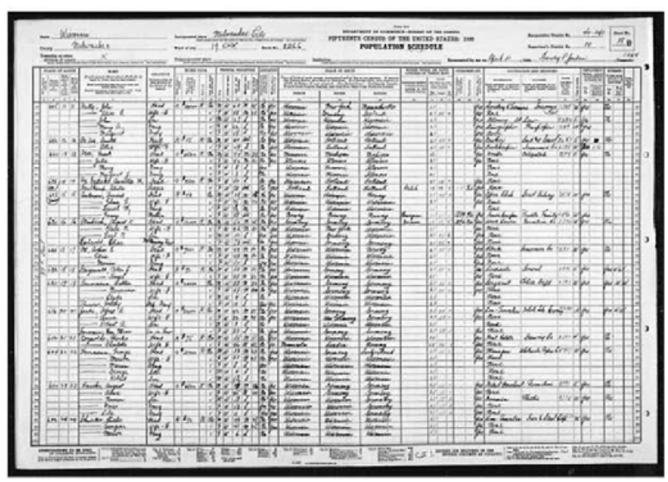
Documents with well defined printed type (e.g. typeset, typed, laser printed, etc.), with high inherent contrast between the ink of the text and the paper background, with clean paper (no staining or discoloration), and no low contrast annotations (such as pencil writing) can be digitized either as a 1-bit file (shown on left) with just black and white pixels (no paper texture is rendered), as an 8-bit grayscale file (shown in the center) with gray tones ranging from black to white, or as a 24-bit RGB color image file (shown on right) with a full range of both tones and colors (notice the paper of the original document is an off-white color). [document- President Nixon's Daily Diary, page 3, 7/20/1969, NARA– Presidential Libraries - Nixon Presidential Materials Staff]



HEADQUARTERS

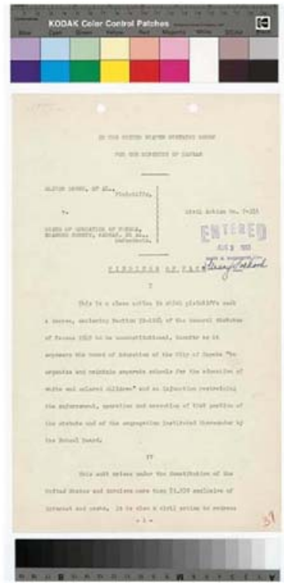
Bureau of Refugees, Freedmen and Abandoned Lands,

DISTRICT OF LOUISIANA.



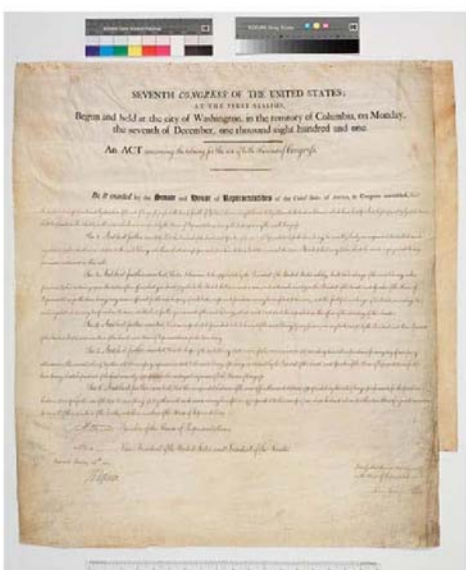
Often grayscale imaging works best for older documents with poor legibility or diffuse characters (e.g. carbon copies, Thermofax/Verifax, etc.), with handwritten annotations or other markings, with low inherent contrast between the text and the paper background, with staining or fading, and with halftone illustrations or photographs included as part of the documents. Many textual documents do not have significant color information and grayscale images will be smaller to store compared to color image files. The document above on the left was scanned directly using a book scanner and the document on the right was scanned from 35mm microfilm using a grayscale microfilm scanner. [document on left- from RG 105, Records of the Bureau of Refugees, Freedmen, and Abandoned Lands, NARA– Old Military and Civil LICON; document on the right- 1930 Census Population Schedule, Milwaukee City, WI, Microfilm Publication T626, Roll 2594, sheet 18B]


United States Military Telegraph.
War Department.
Washington, July 11, 1864
Lieut Gen. Grant
City Point, Va



For textual documents where color is important to the interpretation of the information or content, or there is a desire to produce the most accurate representation, then scanning in color is the most appropriate approach. The document above on the left was scanned from a 4”x5” color copy transparency using a film scanner and the document on the right was scanned directly on a flatbed scanner. [document on left- Telegram from President Lincoln to General Grant, 07/11/1864, RG 107 Records of the Office of the Secretary of War, NARA– Old Military and Civil LICON; document on the right- Brown v. Board, Findings of Fact, 8/3/1951, RG 21 Records of the District Courts of the United States, – Central Plains Region (Kansas City)]

Oversized Records


SEVENTH CONGRESS OF THE UNITED STATES;
AT THE FIRST SESSION,
Begun and held at the city of Washington, in the territory of Columbia, on Monday, the seventh of December, one thousand eight hundred and one.

Generally, oversized refers to documents of any type that do not fit easily onto a standard flatbed scanner. The above parchment document on the left and the large book on the right were digitized using a copy stand with a large-format camera and a scanning digital camera back. Books and other bound materials can be difficult to digitize and often require appropriate types of book cradles to prevent damaging the books. [document on the left- Act Concerning the Library for the Use of both Houses of Congress, Seventh Congress of the US, NARA– Center for Legislative Archives; document on the right- Lists of Aliens Admitted to Citizenship 1790-1860, US Circuit and District Courts, District of South Carolina, Charleston, NARA– Southeast Region (Atlanta)]

Maps, architectural plans, engineering plans, etc. are often oversized. Both of the above documents were scanned using a digital copy stand. [document on left- Map of Illinois, 1836, RG 233 Records of the U.S. House of Representatives, NARA– Center for Legislative Archives; document on right- The Mall and Vicinity, Washington, Sheet # 35-23, RG 79 Records of the National Capitol Parks Commission,– Special Media Archives Services Division]

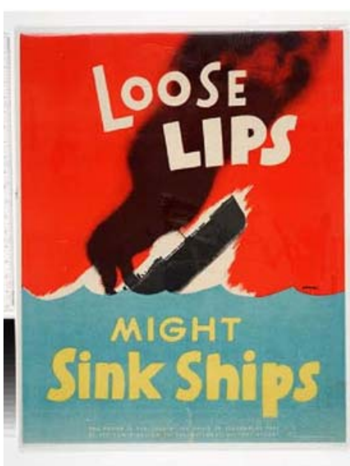
Photographs

There is a wide variety of photographic originals and different types will require different approaches to digitizing. Above on the left is a scan of a modern preservation-quality film duplicate negative of a Mathew Brady collodion wet-plate negative. Since the modern duplicate negative is in good condition and has a neutral image tone, the negative was scanned as a grayscale image on a flatbed scanner. The photograph in the center is a monochrome print from the 1940s that was scanned in color on a flatbed scanner because the image tone is very warm and there is some staining on the print; many older “black-and-white” prints have image tone and it may be more appropriate to scan these monochrome prints in color. The photo on the right is a 4”x5” duplicate color transparency and was scanned in color using a flatbed scanner. [photograph on left- Gen. Edward O.C. Ord and family, ca.1860-ca. 1865, 111-B-5091, RG 111 Records of the Office of the Chief Signal Officer, NARA– Special Media Archives Services Division; photograph in center- Alonzo Bankston, electric furnace operator, Wilson Nitrate Plant, Muscle Shoals, Alabama, 1943, RG 142 Records of the Tennessee Valley Authority, NARA– Southeast Region (Atlanta); photograph on right- Launch of the Apollo 11 Mission, 306-AP-A11-5H-69-H¬1176, RG 306 Records of the U.S. Information Agency, NARA– Special Media Archives Services Division]

Aerial Photographs

Aerial photographs have a lot of fine detail, often require a high degree of enlargement, and may require a higher degree of precision regarding the dimensional accuracy of the scans (compared to textual documents or other types of photographs). The above two grayscale images were produced by scanning film duplicates of the original aerial negatives using a flatbed scanner. The original negative for the image on the left was deteriorated with heavy staining and discoloration, if the original was to be scanned one option would be to scan in color and then to convert to grayscale from an individual color channel that minimizes the appearance of the staining. [photograph on left- Roosevelt Inauguration, 01 / 1941, ON27740, RG373 Records of the Defense Intelligence Agency, NARA– Special Media Archives Services Division; photograph on the right- New Orleans, LA, French Quarter, 12-15-1952, ON367261 / 10280628, RG 145 Records of the Farm Service Agency, NARA– Special Media Archives Services Division]

Graphic Illustrations/Artwork/Originals

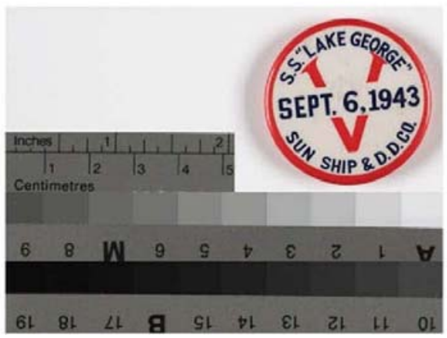


Some originals have graphic content, and will often have some text information as well. The above examples, a poster on the left, a political cartoon in the center, and an artist's rendition on the right all fall into this category.

The most appropriate equipment to digitize these types of records will vary, and will depend on the size of the originals and their physical condition. [document on left- "Loose Lips Might Sink Ships", 44-PA-82, RG 44 Records of the Office of Government Reports, NARA– Special Media Archives Services Division; document in center- "Congress Comes to Order" by Clifford K. Berryman, 12/2/1912, Washington Evening Star, D-021, U.S. Senate Collection, NARA– Center for

Legislative Archives; document on right-Sketch of Simoda (Treaty of Kanagawa, TS 183 AO, RG 11 General Records of the United States Government, NARA - Old Military and Civil Records LICON]

Objects and Artifacts



Objects and artifacts can be photographed using either film or a digital camera. If film is used, then the negatives, slides/transparencies, or prints can be digitized. The images on the left were produced using a digital camera and the image on the right was produced by digitizing a 4"x5" color transparency. [objects on top left- Sword and scabbard, Gift from King of Siam, RG 59 General Records of the Department of State, NARA– Civilian Records LICON; object on bottom left- from Buttons Commemorating the Launch of New Ships at Philadelphia Navy Yard, RG 181 Records of the Naval Districts and Shore Establishments, NARA– Mid Atlantic Region (Center City Philadelphia); objects on right- Chap Stick tubes with hidden microphones, RG 460 Records of the Watergate Special Prosecution Force, NARA– Special Access /FOIA LICON]

Textual Documents, Graphic Illustrations/Artwork, Maps, Plans, and Oversized

Document Character - Original	Recommended Image Parameters	Alternative Minimum
Clean, high-contrast documents with printed type (e.g. laser printed or typeset)	1-bit bitonal mode or 8-bit grayscale - adjust scan resolution to produce a QI of 8 for smallest significant character or 1-bit bitonal mode - 600 ppi* for documents with smallest significant character of 1.0 mm or larger or 8-bit grayscale mode – 400 ppi for documents with smallest significant character of 1.0 mm or larger **NOTE:** Regardless of approach used, adjust scan resolution to produce a minimum pixel measurement across the long dimension of 6,000 lines for 1-bit files and 4,000 lines for 8-bit files *The 600 ppi 1-bit files can be produced via scanning or created/derived from 400 ppi, 8-bit grayscale images.	1-bit bitonal mode - 300 ppi* for documents with smallest significant character of 2.0 mm or larger or 8-bit grayscale mode - 300 ppi for documents with smallest significant character of 1.5 mm or larger *The 300 ppi 1-bit files can be produced via scanning or created/derived from 300 ppi, 8-bit grayscale images.
Documents with poor legibility or diffuse characters (e.g. carbon copies, Thermofax/ Verifax, etc.), handwritten annotations or other markings, low inherent contrast, staining, fading, halftone illustrations, or photographs	8-bit grayscale mode - adjust scan resolution to produce a QI of 8 for smallest significant character or 8-bit grayscale mode - 400 ppi for documents with smallest significant character of 1.0 mm or larger **NOTE:** Regardless of approach used, adjust scan resolution to produce a minimum pixel measurement across the long dimension of 4,000 lines for 8-bit files	8-bit grayscale mode - 300 ppi for documents with smallest significant character of 1.5 mm or larger
Documents as described for grayscale scanning and/or where color is important to the interpretation of the information or content, or desire to produce the most accurate representation	24-bit color mode - adjust scan resolution to produce a QI of 8 for smallest significant character or 24-bit RGB mode - 400 ppi for documents with smallest significant character of 1.0 mm or larger **NOTE:** Regardless of approach used, adjust scan resolution to produce a minimum pixel measurement across the long dimension of 4,000 lines for 24-bit files	24-bit RGB mode - 300 ppi for documents with smallest significant character of 1.5 mm or larger

Photographs - Film / Camera Originals - Black-and-White and Color - Transmission Scanning

<table>
<tr><th>Format - Original</th><th>Recommended Image Parameters</th><th>Alternative Minimum</th></tr>
<tr>
<td>Format range:
▪ 35 mm and medium-format, up to 4”x5”

Size range:
▪ Smaller than 20 square inches</td>
<td>Pixel Array:
▪ 4000 pixels across long dimension of image area, excluding mounts and borders
Resolution:
▪ Scan resolution to be calculated from actual image dimensions - approx. 2800 ppi for 35mm originals and ranging down to approx. 800 ppi for originals approaching 4”x5”
Dimensions:
▪ Sized to match original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. collodion wet-plate negative, pyro developed negatives, stained negatives, etc.), can be produced from a 48-bit RGB file</td>
<td rowspan="3">Pixel Array:
▪ 3000 pixels across long dimension for all rectangular formats and sizes
▪ 2700 pixels by 2700 pixels for square formats regardless of size

Resolution:
▪ Scan resolution calculated from actual image dimensions – approx. 2100 ppi for 35mm originals and ranging down to the appropriate resolution to produce the desired size file from larger originals, approx. 600 ppi for 4”x5” and 300 ppi for 8”x10” originals

Dimension:
▪ File dimensions set to 10” across long dimension at 300 ppi for rectangular formats and to 9”x9” at 300 ppi for square formats

Bit Depth:
▪ 8-bit grayscale mode for black- and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. collodion wet-plate negative, pyro developed negatives, stained negatives, etc.), can be produced from a 48-bit RGB file</td>
</tr>
<tr>
<td>Format range:
▪ 4”x5” and up to 8”x10”

Size range:
▪ Equal to 20 square inches and smaller than 80 square inches</td>
<td>Pixel Array:
▪ 6000 pixels across long dimension of image area, excluding mounts and borders
Resolution:
▪ Scan resolution to be calculated from actual image dimensions – approx. 1200 ppi for 4”x5” originals and ranging down to approx. 600 ppi for 8”x10” originals
Dimensions:
▪ Sized to match original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. collodion wet-plate negative, pyro developed negatives, stained negatives, etc.), can be produced from a 48-bit RGB file</td>
</tr>
<tr>
<td>Format range:
▪ 8”x10” and larger

Size range:
▪ Larger than or equal to 80 square inches</td>
<td>Pixel Array:
▪ 8000 pixels across long dimension of image area, excluding mounts and borders
Resolution:
▪ Scan resolution to be calculated from actual image dimensions – approx. 800 ppi for originals approx. 8”x10” and ranging down to the appropriate resolution to produce the desired size file from larger originals
Dimensions:
▪ Sized to match original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. collodion wet-plate negative, pyro developed negatives, stained negatives, etc.), can be produced from a 48-bit RGB file</td>
</tr>
</table>

Duplicate negatives and copy negatives can introduce problems in recommending scanning specifications, particularly if there is no indication of original size. Any reduction or enlargement in size must be taken into account, if possible. In all cases, reproduction to original size is ideal. For copy negatives or transparencies of prints, use the specifications for that print size. For duplicates (negatives, slides, transparencies), match the original size. However, if original size is not known, the following recommendations are supplied:

- For a copy negative or transparency, scan at a resolution to achieve 4000 pixels across the long dimension.
- For duplicates, follow the scanning recommendations for the size that matches the actual physical dimensions of the duplicate.

For scanning negatives with multiple images on a single negative, see the section on scanning stereographs below. If a ruler has been included in the scan, use it to verify that the image has not been reduced or enlarged before calculating appropriate resolution.

Although many scanning workflows accommodate capturing in 24-bit color, we do not see any benefit at this time to saving the master files of scans produced from modern black-and-white copy negatives and duplicates in RGB. These master scans can be reduced to grayscale in the scanning software or during post-processing editing. However, master scans of camera originals may be kept in RGB, and specifically recommend RGB for any negatives that contain color information as a result of staining, degradation, or intentional color casts.

Scanning Negatives: Often photographic negatives are the most difficult originals to scan. Unlike scanning positives, reflection prints and transparencies/slides, there are no reference images to which to compare scans. Scanning negatives is very much like printing in the darkroom, it is up to the photographer/technician to adjust brightness and contrast to get a good image. Scanning negatives is a very subjective process that is very dependent on the skill of the photographer/technician. Also, most scanners are not as well calibrated for scanning negatives compared to scanning positives.

Often to minimize loss of detail, it is necessary to scan negatives as positives (the image on screen is negative), to invert the images in Photoshop, and then to adjust the images.

If black-and-white negatives are stained or discolored, we recommend making color RGB scans of the negatives and using the channel which minimizes the appearance of the staining/discoloration when viewed as a positive. The image can then be converted to a grayscale image.

On the left is an image of a historic black-and-white film negative that was scanned in color with a positive tonal orientation (the digital image appears the same as the original negative), this represents a reasonably accurate rendition of the original negative. The middle grayscale image shows a direct inversion of the tones, and as shown here, often a direct inversion of a scan of a negative will not produce a well-rendered photographic image. The image on the right illustrates an adjusted version where the brightness and contrast of the image has been optimized (using “Curves” and “Levels” in Adobe Photoshop software) to produce a reasonable representation of the photographic image, these adjustments are very similar to how a photographer prints a negative in the darkroom. [photograph- NRCA-142-INFO01-3169D, RG 142 Records of the TVA, NARA– Southeast Region (Atlanta)]

Photographs - Prints - Black-and-White, Monochrome, and Color - Reflection Scanning:

<table>
<tr><th>Format - Original</th><th>Recommended Image Parameters</th><th>Alternative Minimum</th></tr>
<tr>
<td>Format range:
▪ 8”x10” or smaller

Size range:
▪ Smaller than or equal to 80 square inches</td>
<td>Pixel Array:
▪ 4000 pixels across long dimension of image area, excluding mounts and borders
Resolution:
▪ Scan resolution to be calculated from actual image dimensions – approx. 400 ppi for 8”x10” originals and ranging up to the appropriate resolution to produce the desired size file from smaller originals, approx. 570 ppi for 5”x7” and 800 ppi for 4”x5” or 3.5”x5” originals
Dimensions:
▪ Sized to match the original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. albumen prints or other historic print processes), can be produced from a 48-bit RGB file</td>
<td rowspan="3">Pixel Array:
▪ 3000 pixels across long dimension for all rectangular formats and sizes
▪ 2700 pixels by 2700 pixels for square formats regardless of size

Resolution:
▪ Scan resolution calculated from actual image dimensions – approx. 2100 ppi for 35mm originals and ranging down to the appropriate resolution to produce the desired size file from larger originals, approx. 600 ppi for 4”x5” and 300 ppi for 8”x10” originals

Dimension:
▪ File dimensions set to 10” across long dimension at 300 ppi for rectangular formats and to 9”x9” at 300 ppi for square formats

Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. collodion wet-plate negative, pyro developed negatives, stained negatives, etc.), can be produced from a 48-bit RGB file</td>
</tr>
<tr>
<td>Format range:
▪ Larger than 8”x10” and up to 11”x14”

Size range:
▪ Larger than 80 square inches and smaller than 154 square inches</td>
<td>Pixel Array:
▪ 6000 pixels across long dimension of image area, excluding mounts and borders
Resolution:
▪ Scan resolution to be calculated from actual image dimensions – approx. 600 ppi for originals approx. 8”x10” and ranging down to approx. 430 ppi for 11”x14” originals
Dimensions:
▪ Sized to match the original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. albumen prints or other historic print processes), can be produced from a 48-bit RGB file</td>
</tr>
<tr>
<td>Format range:
▪ Larger than 11”x14”

Size range:
▪ Equal to or larger than 154 square inches</td>
<td>Pixel Array:
▪ 8000 pixels across long dimension of image area, excluding mounts and borders
Resolution:
▪ Scan resolution to be calculated from actual image dimensions – approx. 570 ppi for originals approx. 11”x14” and ranging down to the appropriate resolution to produce the desired size file from larger originals
Dimensions:
▪ Sized to match the original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. albumen prints or other historic print processes), can be produced from a 48-bit RGB file</td>
</tr>
</table>

For stereograph images and other multiple image prints, modified recommended scanning specifications are to scan to original size (length of both photos and mount) and add 2000 pixels to the long dimension, in the event that only one of the photographs is requested for high-quality reproduction. For example, if the stereograph is 8” on the long dimension, a resolution of 500 ppi would be required to achieve 4000 pixels across the long dimension for that size format; in this case, adding 2000 pixels to the long dimension would require that the stereograph be scanned at 750 ppi to achieve the desired 6000 pixels across the long dimension.

For photographic prints, size measurements for determining appropriate resolution are based on the size of the image area only, excluding any borders, frames, or mounts. However, in order to show that the entire record has been captured, it is good practice to capture the border area in the master scan file. In cases where a small image is mounted on a large board (particularly where large file sizes may be an issue), it may be desirable to scan the image area only at the appropriate resolution for its size, and then scan the entire mount at a resolution that achieves 4000 pixels across the long dimension.

Aerial - Transmission Scanning

<table>
<tr><th>Format - Original</th><th>Recommended Image Parameters*</th><th>Alternative Minimum</th></tr>
<tr>
<td>Format range:
▪ 70mm wide and medium format roll film

Size range:
▪ Smaller than 10 square inches</td>
<td>Pixel Array:
▪ 6000 pixels across long dimension of image area, excluding borders
Resolution:
▪ Scan resolution to be calculated from actual image dimensions – approx. 2700 ppi for 70mm originals and ranging down to the appropriate resolution to produce the desired size file from larger originals
Dimensions:
▪ Sized to match original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RBG mode for color and monochrome (stained negatives), can be produced from a 48-bit RGB file</td>
<td rowspan="3">Pixel Array:
▪ 4000 pixels across long dimension of image area

Resolution:
▪ Scan resolution calculated from actual image dimensions – approx. 1800 ppi for 6cm x 6cm originals and ranging down to the appropriate resolution to produce the desired size file from large originals, approx. 800 ppi for 4”x5” and 400 ppi for 8”x10” originals

Dimension:
▪ File dimensions set to 10” across long dimension at 400 ppi for all formats

Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. stained negatives), can be produced from a 48-bit RGB file</td>
</tr>
<tr>
<td>Format range:
▪ 127mm wide roll film, 4”x5” and up to 5”x7” sheet film

Size range:
▪ Equal to 10 square inches and up to 35 square inches</td>
<td>Pixel Array:
▪ 8000 pixels across long dimension of image area, excluding borders
Resolution:
▪ Scan to be calculated from actual image dimensions – approx. 1600 ppi for 4”x5” originals and ranging down to approx.1100 ppi for 5”x7” originals
Dimensions:
▪ Sized to match original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (stained negatives), can be produced from a 48-bit RGB file</td>
</tr>
<tr>
<td>Format range:
▪ Larger than 127mm wide roll film and larger than 5”x7” sheet film

Size range:
▪ Larger than 35 square inches</td>
<td>Pixel Array:
▪ 10000 pixels across long dimension of image area, excluding borders
Resolution:
▪ Scan resolution to be calculated from actual image dimensions – approx. 2000 ppi for 5”x5” originals and ranging down to the appropriate resolution to produce the desired size file from larger originals
Dimensions:
▪ Sized to match original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. stained negatives), can be produced from a 48-bit RGB file</td>
</tr>
</table>

*If scans of aerial photography will be used for oversized reproduction, follow the scanning recommendations for the next largest format (e.g., if your original is 70mm wide, follow the specifications for 127mm wide roll film to achieve 8000 pixels across the long dimensions.

Aerial - Reflection Scanning:

<table>
<tr><th>Format - Original</th><th>Recommended Image Parameters*</th><th>Alternative Minimum</th></tr>
<tr><td>Format range:
▪ Smaller than 8”x10”

Size range:
▪ Smaller than 80 square inches</td><td>Pixel Array:
▪ 4000 pixels across long dimension of image area, excluding mounts and borders
Resolution:
▪ Scan resolution to be calculated from actual image dimensions – approx. 400 ppi for originals approx. 8”x10” and ranging up to the appropriate resolution to produce the desired size file from smaller originals, approx. 570 ppi for 5”x7” and 800 ppi for 4”x5” originals
Dimensions:
▪ Sized to match the original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. discolored prints), can be produced from a 48-bit RGB file</td><td rowspan="3">Pixel Array:
▪ 3000 pixels across long dimension of image area

Resolution:
▪ Scan resolution to be calculated from actual image dimensions – approx. 300 ppi for 8”x10” originals and ranging up to the appropriate resolution to produce the desired size file from smaller originals, approx. 570 ppi for 5”x7” and 800 ppi for 4”x5” or 3.5”x5” originals

Dimensions:
▪ Sized to match the original, no magnification or reduction

Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. discoloured prints), can be produced from a 48-bit RGB file</td></tr>
<tr><td>Format range:
▪ 8”x10” and up to 11”x14”

Size range:
▪ Equal to 80 square inches and up to 154 square inches</td><td>Pixel Array:
▪ 6000 pixels across long dimension of image area, excluding mounts and borders
Resolution:
▪ Scan resolution to be calculated from actual image dimensions – approx. 600 ppi for 8”x10” originals and ranging down to approx. 430 ppi for 11”x14” originals
Dimensions:
▪ Sized to match the original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. discolored prints), can be produced from a 48-bit RGB file</td></tr>
<tr><td>Format range:
▪ Larger than 11”x14”

Size range:
▪ Larger than 154 square inches</td><td>Pixel Array:
▪ 8000 pixels across long dimension of image area, excluding mounts and borders
Resolution:
▪ Scan resolution to be calculated from actual image dimensions – approx. 570 ppi for 11”x14” originals and ranging down to the appropriate resolution to produce the desired size file from larger originals
Dimensions:
▪ Sized to match the original, no magnification or reduction
Bit Depth:
▪ 8-bit grayscale mode for black-and-white, can be produced from a 16-bit grayscale file
▪ 24-bit RGB mode for color and monochrome (e.g. discolored prints), can be produced from a 48-bit RGB file</td></tr>
</table>

*If scans of aerial photography will be used for oversized reproduction, follow the scanning recommendations for the next largest format (e.g., if your original is 8”x10”, follow the specifications for formats larger than 8”x10” to achieve 6000 pixels across the long dimensions.

Objects and Artifacts

Recommended Image Parameters	Alternative Minimum
10 to 16 megapixel 24-bit RGB mode image, can be produced from a 48-bit RGB file. If scanning photographic copies of objects and artifacts, see recommended requirements in the appropriate photo charts above.	6 megapixel 24-bit RGB mode image, can be produced from a 48-bit RGB file. If scanning photographic copies of objects and artifacts, see minimum requirements in the appropriate photo charts above.

High resolution digital photography requirements:

- Images equivalent to 35mm film photography (6 megapixels to 14 megapixels), to medium format film photography (12 megapixels to 22 megapixels), or to large format film photography (18 megapixels to 200 megapixels).
- Images for photo quality prints and printed reproductions with magazine quality halftones, with maximum image quality at a variety of sizes.
- "Megapixel" is millions of pixels, the megapixel measurement is calculated by multiplying the pixel array values: image width in pixels x image height in pixels.

Actual pixel dimensions and aspect ratio will vary depending on digital camera - illustrative sizes, dimensions, and proportions are:

- 35mm equivalent - Minimum pixel array of 3,000 pixels by 2,000 pixels (6 megapixels, usual default resolution of 72 ppi at 41.7" by 27.8" or equivalent such as 300 ppi at 10" by 6.7"). Pixel array up to 4,500 pixels by 3,100 pixels (14 megapixels, usual default resolution of 72 ppi at 62.5" by 43" or equivalent such as 300 ppi at 15" by 10.3").
- Medium format equivalent - Minimum pixel array of 4,000 pixels by 3,000 pixels (12 megapixels, usual default resolution of 72 ppi at 55.6" by 41.7" or equivalent such as 300 ppi at 13.3" by 10"). Pixel array up to 5,200 pixels by 4,200 pixels (22 megapixels, usual default resolution of 72 ppi at 72.2" by 58.3" or equivalent such as 300 ppi at 17.3" by 14").
- Large format equivalent - Minimum pixel array of 4,800 pixels by 3,700 pixels (18 megapixels, usual default resolution of 72 ppi at 66.7" by 51.4" or equivalent such as 300 ppi at 16" by 12.5"). Pixel array up to 16,000 pixels by 12,500 pixels (200 megapixels, usual default resolution of 72 ppi at 222.2" by 173.6" or equivalent such as 300 ppi at 53.3" by 41.7").

File Formats – Image files shall be saved using the following formats:

- Uncompressed TIFF (.tif, sometimes called a raw digital camera file) or LZW compressed TIFF preferred for medium and high resolution requirements.
- JPEG File Interchange Format (JFIF, JPEG, or .jpg) at highest quality (least compressed setting) acceptable for medium and high resolution requirements.
- JPEG Interchange Format (JFIF, JPEG, or .jpg) at any compression setting acceptable for low resolution requirements, depending on the subject matter of the photograph.
- Using the TIFF format and JFIF/JPEG format with high-quality low compression will result in relatively large image file sizes. Consider using larger memory cards, such as 128 MB or larger, or connecting the camera directly to a computer. Select digital cameras that use common or popular memory card formats.

Image Quality - Digital cameras shall produce high quality image files, including:

- No clipping of image detail in the highlights and shadows for a variety of lighting conditions.
- Accurate color and tone reproduction and color saturation for a variety of lighting conditions.
- Image files may be adjusted after photography using image processing software, such as Adobe Photoshop or JASC Paint Shop Pro. It is desirable to get a good image directly from the camera and to do as little adjustment after photography.
- Digital images shall have minimal image noise and other artifacts that degrade image quality.
- Subject of the photographs shall be in focus, using either auto or manual focus.

- Use of digital zoom feature may have a detrimental effect on the image quality; a smaller portion of the overall image is interpolated to a larger file (effectively lowering resolution).

White Balance – Digital cameras shall be used on automatic white balance or the white balance shall be selected manually to match the light source.

Color Profile – Image files saved with a custom ICC image profile (done in camera or profile produced after photography using profiling software) or a standard color space like sRGB should be converted to a standard wide-gamut color space like Adobe RGB 1998.

Header Data – If camera supports EXIF header data, data in all tags shall be saved.

Image Stitching - Some cameras and many software applications will stitch multiple images into a single image, such as stitching several photographs together to create a composite or a panorama. The stitching process identifies common features within overlapping images and merges the images along the areas of overlap. This process may cause some image degradation. Consider saving and maintaining both the individual source files and the stitched file.

V. File Format Comparison

As stated earlier, the choice of file format has a direct affect on the performance of the digital image as well as implications for long term management of the image. Future preservation policy decisions, such as what level of preservation service to apply, are often made on a format-specific basis*. A selection of file formats commonly used for digital still raster images are listed below. The first table lists general technical characteristics to consider when choosing an appropriate file format as well as a statement on their recommended use in imaging projects. Generally, these are all well-established formats that do not pose a big risk to the preservation of content information; however, it is advised that an assessment of the potential longevity and future functionality of these formats be undertaken for any digital imaging project. The second table attempts to summarize some of these concerns.

File Format	Technical Considerations	Recommended Use
TIFF	▪ "De facto" raster image format used for master files ▪ Simply encoded raster-based format ▪ Accommodates internal technical metadata in header/extensible and customizable header tags ▪ Supports Adobe's XMP (Extensible Metadata Platform) ▪ Accommodates large number of color spaces and profiles ▪ Supports device independent color space (CIE L*a*b) ▪ Uncompressed; lossless compression (Supports multiple compression types for 1-bit files). JPEG compression not recommended in TIFF file ▪ High-bit compatible ▪ Can support layers, alpha channels ▪ Accommodates large file sizes ▪ Anticipate greater preservation support in repository settings; preferred raster image format for preservation ▪ Widely supported and used ▪ Long track record (format is over 10 years old) ▪ Potential loss of Adobe support of TIFF in favor of PDF? ▪ Not suitable as access file–no native support in current web browsers	Preferred format for production master file
JPEG 2000	▪ Increasingly considered as a viable format for master image files, but not yet widely adopted ▪ More complex model for encoding data (content is not saved as raster data) ▪ Supports multiple resolutions ▪ Extended version supports color profiles ▪ Extended version supports layers ▪ Includes additional compression algorithms to JPEG (wavelet, lossless)	Rapidly gaining acceptance as a format for production master file–however, not currently widely implemented (or TIFF files are also being saved alongside JPEG 2000 files as master formats (?))

File Format	Technical Considerations	Recommended Use
	▪ Support for extensive metadata encoded in XML "boxes;" particularly technical, descriptive, and rights metadata. Supports IPTC information; mapping to Dublin Core.	
JFIF/JPEG	▪ Lossy compression, but most software allows for adjustable level of compression ▪ Presence of compression artifacts ▪ Smaller files ▪ High-bit compatible ▪ Longer decompression time ▪ Supports only a limited set of internal technical metadata ▪ Supports a limited number of color spaces ▪ Not suitable format for editing image files–saving, processing, and resaving results in degradation of image quality after about 3 saves	Access derivative file use only–not recommended for text or line drawings
PDF	▪ Intended to be a highly structured page description language that can contain embedded objects, such as raster images, in their respective formats. ▪ Works better as a container for multiple logical objects that make up a coherent whole or composite document ▪ More complex format due to embedded/externally linked objects ▪ Implements Adobe's XMP specification for embedding metadata in XML ▪ Can use different compression on different parts of the file; supports multiple compression schemes ▪ Supports a limited number of color spaces	Not recommended for production master files
PDF/A	▪	
PNG	▪ Simple raster format ▪ High-bit compatible ▪ Lossless compression ▪ Supports alpha channels ▪ Not widely adopted by imaging community ▪ Native support available in later web browsers as access file	Possible format for production master file–not currently widely implemented
GIF	▪ Lossy (high color) and lossless compression ▪ Limited color palette ▪ 8-bit maximum, color images are dithered ▪ Short decompression time	Access derivative file use only–recommend for text records
[ASCII]	▪ For image files converted to text ▪ Potential loss to look and feel of document/formatting	N/A
[XML]	▪ For image files converted to text ▪ Hierarchical structure ▪ Good for encoding digital library-like objects or records ▪ Allows for fast and efficient end-user searching for text retrieval ▪ Easily exchanged across platforms/systems	N/A

* For example, DSpace directly associates various levels of preservation services with file formats–categorized as supported formats, known formats, and unknown formats. See http://dspace.org/faqs/index.html#preserve. The Florida Center for Library Automation (FCLA) specifies preferred, acceptable, and bit-level preservation only categories for certain file formats for their digital archive. See http://www.fcla.edu/digitalArchive/pdfs/recFormats.pdf.

For additional information on research into file format longevity, see Sustainability of Digital Formats: Planning for Library of Congress Collections at: http://www.digitalpreservation.gov/formats/from which many of the considerations below were taken; see also the Global Digital Format Registry (GDFR) at http://hul.harvard.edu/gdfr/ for discussion of a centralized, trusted registry for information about file formats.

Longevity Considerations	
Consider	**Questions to ask**
Documentation	For both proprietary and open standard formats, is deep technical documentation publicly and fully available? Is it maintained for older versions of the format?
Stability	Is the format supported by current applications? Is the current version backward-compatible? Are there frequent updates to the format or the specification?
Metadata	Does the format allow for self-documentation? Does the format support extensive embedded metadata beyond what is necessary for normal rendering of a file? Can the file support a basic level of descriptive, technical, administrative, and rights metadata? Can metadata be encoded and stored in XML or other standardized formats? Is metadata easily extracted from the file?
Presentation	Does the format contain embedded objects (e.g. fonts, raster images) and/or link out to external objects? Does the format provide functionality for preserving the layout and structure of document, if this is important?
Complexity	Simple raster formats are preferred. Can the file be easily unpacked? Can content be easily separated from the container? Is “uncompressed” an option for storing data? Does the format incorporate external programs (e.g., Javascript, etc.)? Complexity of format is often associated with risk management–more complex formats are assumed to be harder to decode. However, some formats are by necessity complex based on their purpose and intended functionality. Complex formats should not be avoided solely on the basis that they are forecast to be difficult to preserve, at the expense of using the best format for the use of the data it contains.
Adoption	Is the format widely used by the imaging community in cultural institutions? How is it generally used by these stakeholders–as a master format, a delivery format?
Continuity	How long has the format been in existence? Is the file format mature? (Most of the image formats in the table above have been in existence for over 10 years.)
Protection	Does the format accommodate error detection and correction mechanisms and encryption options? These are related to complexity of the file. In general, encryption and digital signatures may deter full preservation service levels.
Compression algorithms	Does the format use standard algorithms? In general, compression use in files may deter full preservation service levels; however, this may have less to do with file complexity and more to do with patent issues surrounding specific compression algorithms.
Interoperability	Is the format supported by many software applications/ OS platforms or is it linked closely with a specific application? Are there numerous applications that utilize this format? Have useful tools been built up around the format? Are there open source tools available to use and develop the format? Is access functionality improved by native support in web browsers?
Dependencies	Does the format require a plug-in for viewing if appropriate software is not available, or rely on external programs to function?
Significant properties	Does the format accommodate high-bit, high-resolution (detail), color accuracy, multiple compression options? (These are all technical qualities important to master image files).
Ease of transformation/preservation	Is it likely that the format will be supported for full functional preservation in a repository setting, or can guarantees currently only be made at the bitstream

Longevity Considerations	
Consider	**Questions to ask**
	(content data) level (where only limited characteristics of the format are maintained)?
Packaging formats	In general, packaging formats such as zip and tar files should be acceptable as transfer mechanisms for image file formats. These are not normally used for storage/archiving.

VI. METADATA

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 – and is therefore directly associated with most of the steps in a digital imaging project workflow: file naming, capture, processing, quality control, production tracking, search and retrieval design, storage, and long-term management. 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.

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 schemes, 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.

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).

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 on 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.

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

Common Metadata Types

Several categories of metadata are associated with the creation and management of master 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/

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, dimension, and condition. Descriptive metadata is usually highly structured and often conforms to one or more standardized, published schemes, 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[2] set to capture minimal descriptive metadata information *if* 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 important 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, but 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 scanned as well as a local identifier should be captured. If keying of captions into a database is prohibitive, if possible scan captions as part of the image itself. 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

[2] Dublin Core Metadata Initiative, (http://dublincore.org/usage/terms/dc/current-elements/). 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.

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.

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 Harvard University Library's Digital Repository Services (DRS) User Manual for Data Loading, Version 2.04 at http://hul.harvard.edu/ois/systems/drs/drs_load_manual.pdf, particularly Section 5.0, "DTD Element Descriptions" for application of administrative metadata in a repository setting; also the California Digital Library's Guidelines for Digital Objects at http://www.cdlib.org/inside/diglib/guidelines/. The Library of Congress has defined a data dictionary for various formats in the context of METS, Data Dictionary for Administrative Metadata for 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.

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 both 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.

Metadata element sets for intellectual property and rights information are still in development, but they will be much more detailed than statements that define reproduction and distribution policies. 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: http://cosimo.stanford.edu/sdr/metsrights.xsd.

For additional information on rights management, see: Peter B. Hirtle, "Archives or Assets?" at http://www.archivists.org/governance/presidential/hirtle.asp; 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; Adrienne Muir, "Copyright and Licensing for Digital Preservation," at http://www.cilip.org.uk/publications/updatemagazine/archive/archive2003/june/update0306c.htm; Karen Coyle, Rights Expression Languages, A Report to the Library of Congress, February 2004, available at http://www.loc.gov/standards/relreport.pdf; MPEG-21 Overview v.5 contains a discussion on intellectual property and rights at http://www.chiariglione.org/mpeg/standards/mpeg-21/mpeg-21.htm; for tables that reference when works pass into the public domain, see Peter Hirtle, "When Works Pass Into the Public Domain in the United States: Copyright Term for Archivists and Librarians," at http://www.copyright.cornell.edu/public_domain/ and Mary Minow, "Library Digitization Projects: Copyrighted Works that have Expired into the Public Domain" at http://www.librarylaw.com/DigitizationTable.htm; and for a comprehensive discussion on libraries and copyright, see: Mary Minow, *Library Digitization Projects and Copyright* at http://www.llrx.com/features/digitization.htm.

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 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 http://www.niso.org/home. It is a comprehensive technical metadata set based on the Tagged Image File Format 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/.

See also the TIFF 6.0 Specification at http://partners.adobe.com/public/developer/en/tiff/TIFF6.pdf as well as the Digital Imaging Group's DIG 35 metadata element set at http://www.bgbm.fu-berlin.de/TDWG/acc/Documents/DIG35-v1.1WD-010416.pdf; and Harvard University Library's Administrative Metadata for Digital Still Images data dictionary at http://preserve.harvard.edu/resources/imagemetadata.pdf

Initiatives such as the Global Digital Format Registry (http://hul.harvard.edu/gdfr/) could potentially help in reducing the number of metadata elements that need to be recorded about a file or group of files regarding file format information necessary for preservation functions. Information maintained in the Registry could be pointed to instead of recorded for each file or batch of files.

Embedded Metadata

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 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. See Section ?. Storage for further discussion on this topic.

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 back 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 they describe 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.

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.

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, http://public.ccsds.org/publications/archive/650x0b1.pdf), 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-processible 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 http://www.oclc.org/research/projects/pmwg/pm_framework.pdf and *Preservation Metadata for Digital Objects: A Review of the State of the Art* at http://www.oclc.org/research/projects/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/.

For some examples of implementations of preservation metadata element sets at specific institutions, see: OCLC Digital Archive Metadata, at http://www.oclc.org/support/documentation/pdf/da_metadata_elements.pdf; Technical Metadata for the Long-Term Management of Digital Materials from the Defense Virtual Library, at http://www.stormingmedia.us/16/1670/A167004.html; and The National Library of New Zealand, Metadata Standard Framework, Preservation Metadata, at http://www.natlib.govt.nz/files/4initiatives_metaschema_revised.pdf.

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.

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.

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 partially be determined 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. Guidelines for implementing Dublin Core in XML are also available at: http://dublincore.org/documents/2002/09/09/dc-xml-guidelines/.

Adobe's Extensible Metadata Platform (XMP) is another emerging, 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 or stored in XML "packets" (these describe how the metadata is embedded in the file). 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.

Adherence to agreed-upon conventions and terminology?

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.

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).

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 redo 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.

File Formats

We recommend the Tagged Image File Format or TIFF for master files. Use TIFF version 6, with Intel (Windows) byte order. For additional information on file formats for masters, see Section ?, File Format Comparison.

Uncompressed files are recommended, particularly if files are not actively managed, such as storage on CD-ROM or DVD-ROM. If files are actively managed in a digital repository, then you may want to consider using either LZW or ZIP lossless compression for the TIFF files. Do not use JPEG compression within the TIFF format.

Many institutions are moving towards adopting JPEG2000 as a valid master image file format, and are working on defining a profile for the JPEG2000 format.

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.

In general, we recommend that 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.
- 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.

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.

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.

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.

VII. STORAGE RECOMMENDATIONS

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

Currently, we do not recommend that CD-ROMs or DVD-Rs be used as a long-term storage medium. However, if images are stored on CD-ROMs, we recommend using high quality or “archival” quality CD-Rs (such as Mitsui Gold Archive CD-Rs). The term “archival” indicates the materials used to manufacture the CD-R (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 have found files stored on brand name CD-Rs that we have not been able to open less than a year after they have been written to the media. We recommend not using inexpensive or non-brand name CD-Rs, because generally they will be less stable, less durable, and more prone to recording problems. 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 CD-ROMs should be in place. In addition, all copies of the CD-ROMs 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-R storage will be problematic. DVD-Rs may be considered for large projects, however, DVD formats are not as standardized as the lower-capacity CD-ROM formats, and compatibility and obsolescence in the near future is likely to be a problem.

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. Is it important to realize the protection of these investments will require the active management of both the image files and the associated metadata. Storing files to CD-R or DVD-R 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 a digital repository, see, www.nla.gov.au/padi/ and www.dpconline.org, as well as RLG's and OCLC's "Trusted Digital Repositories: Attributes and Responsibilities," at http://www.oclc.org/programs/ourwork/past/trustedrep/repositories.pdf, "Trustworthy Repositories Audit Certification (TRAC): Criteria and Checklist" at http://www.crl.edu/PDF/trac.pdf , and DRAMBORA (Digital Repository Audit Method Based On Risk Assessment) at http://www.repositoryaudit.eu/ The Open Archival Information System (OAIS) reference model standard describes the functionality of a digital repository- see http://ssdoo.gsfc.nasa.gov/nost/isoas/overview.html.

The General Printing Office (GPO) has developed the Federal Digital System (FDsys) to provide public access to government information submitted by Congress and federal agencies, and preserves this information as technology changes. See http://fdsys.gpo.gov/fdsys/search/home.action for more information. NARA is working to develop a large scale IT infrastructure for the management of, preservation of, and access to electronic records, the Electronic Records Archive (ERA) project. Information is available at http://www.archives.gov/electronic_records_archives/index.html. ERA will be an appropriate repository for managing and providing access to digital copies of physical records.

Do we want to mention other repository implementations, such as DAITSS, DSpace, EPrints, Fedora, Digital Commons, etc.?

VIII. QUALITY MANAGEMENT

This section will incorporate the QC/QA document.

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 address 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 and this is followed by a second check by another person.

A quality control program should be initiated, documented, and maintained throughout all phases of digital conversion. The quality control plan should address all specifications and reporting requirements associated with each phase of the conversion project.

Completeness

We recommend verification that 100% of the required images files and associated metadata have been completed or provided.

Inspection of Digital Image Files

The overall quality of the digital images and metadata will be evaluated using the following procedures. The 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
- 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

- 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.

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 an 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 TIFF 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 TIFF 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.

Documentation

Quality control data (such as logs, reports, decisions) should be captured in a formal system and should become an integral part of the image metadata at the file or the project level. This data may have long-term value that could have an impact on future preservation decisions.

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.

APPENDIX A: Digitizing for Preservation Reformatting of Photographs

In order to consider using digitization as a method of preservation reformatting it will be necessary to specify much more about the characteristics and quality of the digital images than just specifying spatial resolution.

The following chart provides a comparison of image characteristics for preservation master image files and production master image files

	Preservation Master Files	Production Master Files
Tone reproduction	We need to use well defined, conceptually valid, and agreed upon approaches to tone reproduction that inform current and future users about the nature of the originals that were digitized. There are currently no agreed upon approaches to tone reproduction appropriate for preservation digitization. If analog preservation reformatting is used as a model, then one analogous conceptual approach to tone reproduction would be to digitize so the density values of the originals are rendered in a linear relationship to the lightness channel in the LAB color mode. The lightness channel should be correlated to specified density ranges appropriate for different types of originals- as examples, for most reflection scanning a range of 2.0 to 2.2, for transmission scanning of most older photographic negatives a range of 2.0 to 2.2, and for transmission scanning of color transparencies/slides a range of 3.2 to 3.8. Many tone reproduction approaches that tell us about the nature of the originals are likely to produce master image files that are not directly usable on-screen or for printing without adjustment. It will be necessary to make production master derivative files brought to a common rendition to facilitate use. For many types of master files this will be a very manual process (like images from photographic negatives) and will not lend itself to automation. The need for a known rendering in regards to originals argues against saving raw and unadjusted files as preservation masters. For some types of originals, a tone reproduction based upon average or generic monitor display (as described in these Technical Guidelines) may be appropriate for preservation master files.	Images adjusted to achieve a common rendering and to facilitate the use of the files and batch processing. Tone reproduction matched to generic representation – tones distributed in a non-linear fashion.
Tonal Orientation	For preservation digitization the tonal orientation (positive or negative) for master files should be the same as the originals. This approach informs users about the nature of the originals, the images of positive originals appear positive and the images of photographic negatives appear negative. This approach would require production master image files be produced of images of negatives and the tonal orientation inverted to positive images. The master image files of photographic negatives will not be directly usable.	All images have positive tonal orientation.
Color reproduction	We need to use well defined, conceptually valid, and agreed upon approaches to color reproduction that inform current and future users about the nature of the originals that were digitized. There are currently no agreed upon approaches to color reproduction appropriate for preservation digitization. Device independence and independence from current technical approaches that may change over time (such as ICC color management) are desirable. Conceptually, LAB color mode may be more appropriate than RGB mode. Although, since scanners/digital cameras all capture in RGB, the images have to be converted to LAB and this process does entail potential loss of image quality. Also, LAB master files would have to be converted back to RGB to be used, another transformation and potential loss of image quality.	Images adjusted to achieve a common rendering and to facilitate the use of the files and batch processing. Color reproduction matched to generic RGB color space. Intent is to be able to use files both within and outside of current ICC color managed process.

	Preservation Master Files	Production Master Files
	Also, the imaging field is looking at multi-spectral imaging to provide the best color reproduction and to eliminate problems like metamerisms. At this time, standard computer software is not capable of dealing with multi-spectral data. Also, depending on the number of bands of wavelengths sampled, the amount of data generated is significantly more than standard 3-channel color digitization. If multi-spectral imaging was feasible from a technical perspective, it would be preferable for preservation digitization. However, at this time there is no simple raster image format that could be used for storing multi-spectral data. The JPEG 2000 file format could be used, but this is a high-encoded wavelet based format that does not save the raster data (it does not save the actual bits that represent the pixels, instead it recreates the data representing the pixels). To use a simple raster image format like TIFF it would probably be necessary to convert the multi-spectral data to 3-channel RGB data; hopefully this would produce a very accurate RGB file, but the multispectral data would not be saved. Images adjusted to achieve a common rendering and to facilitate the use of the files and batch processing. Color reproduction matched to generic RGB color space. Intent is to be able to use files both within and outside of current ICC color managed process.	
Bit depth	High bit-depth digitization is preferred, either 16-bit grayscale images or 48-bit RGB color images. Standard 8-bit per channel imaging has only 256 levels of shading per channel, while 16-bit per channel imaging has thousands of shades per channel making them more like the analog originals. High bit-depth necessary for standard 3-channel color digitization to achieve the widest gamut color reproduction. Currently, it is difficult to verify the quality of high-bit image files.	Traditional 8-bit grayscale and 24-bit RGB files produced to an appropriate quality level are sufficient.
Resolution	Requires sufficient resolution to capture all the significant detail in originals. Currently the digital library community seems to be reaching a consensus on appropriate resolution levels for preservation digitization of text based originals – generally 400 ppi for grayscale and color digitization is considered sufficient as long as a QI of 8 is maintained for all significant text. This approach is based on typical legibility achieved on 35mm microfilm (the current standard for preservation reformatting of text-based originals), and studies of human perception indicate this is a reasonable threshold in regards to the level of detail perceived by the naked eye (without magnification). Certainly all originals have extremely fine detail that is not accurately rendered at 400 ppi. Also, for some reproduction requirements this resolution level may be too low, although the need for very large reproduction is infrequent. Unlike text-based originals, it is very difficult to determine appropriate resolution levels for preservation digitization of many types of photographic originals. For analog photographic preservation duplication, the common approach is to use photographic films that have finer grain and higher resolution than the majority of originals being duplicated. The analogous approach in the digital environment would be to digitize all photographic camera originals at a resolution of 3,000 ppi to 4,000 ppi regardless of size. Desired resolution levels may be difficult to achieve given limitations of current scanners.	Generally, current approaches are acceptable (see requirements in these *Technical Guidelines*).

	Preservation Master Files	Production Master Files
File size	The combination of both high bit-depth and high resolution digitization will result in large to extremely large image files. These files will be both difficult and expensive to manage and maintain. If multi-spectral image is used, file sizes will be even larger. Although, generally it is assumed a compressed format like JPEG 2000 would be used and would compensate for some of the larger amount of data.	Moderate to large files sizes.
Other image quality parameters	Preservation master images should be produced on equipment that meets the appropriate levels for the following image quality parameters at a minimum: ▪ Ability to capture and render large dynamic ranges for all originals. ▪ Appropriate spatial frequency response to capture accurately fine detail at desired scanning resolutions. ▪ Low image noise over entire tonal range and for both reflective and transmissive originals. ▪ Accurate channel registration for originals digitized in color. ▪ Uniform images without tone and color variation due to deficiencies of the scanner or digitization set-up. ▪ Dimensionally accurate and consistent images. ▪ Free from all obvious imaging defects. We need to use well defined, conceptually valid, and agreed upon approaches to these image quality parameters. There are currently no agreed upon approaches appropriate for preservation digitization.	Generally, current equipment and approaches are acceptable (see requirements in these *Technical Guidelines*).
Three dimensional and other physical aspects of documents	We need to acknowledge digitization is a process that converts three-dimensional objects (most of which are very flat, but are three-dimensional nonetheless) into two-dimensional images or representations. Most scanners are designed with lighting to minimize the three dimensional aspects of the original documents being scanned, in order to emphasize the legibility of the text or writing. So not all of the three-dimensional aspects of the documents are recorded well and in many cases are not recorded at all; including properties and features like paper texture and fibers, paper watermarks and laid lines, folds and/or creases, embossed seals, etc. Loss of three-dimensional information may influence a range of archival/curatorial concerns regarding preservation reformatting. These concerns are not unique to digital reformatting, traditional approaches to preservation reformatting, such as microfilming, photocopying (electrophotographic copying on archival bond), and photographic copying/duplication have the same limitations – they produce two-dimensional representations of three-dimensional originals. One example of a concern about rendering three-dimensional aspects of documents that has legal implications is documents with embossed seals and questions about the authenticity of the digital representation of the documents when the seals are not visible and/or legible in the digital images (a common problem, see Digitization Specifications for Record Types for a short discussion of lighting techniques to improve legibility of embossed seals). Other issues that may need to be considered and appropriate approaches defined prior to starting any reformatting include, but limited to, the following: ▪ Digitize front and/or back of each document or page – even if no information is on one side. ▪ Reflection and/or transmission scanning for all materials – to record watermarks, laid lines, paper structure and texture, any damage to the paper, etc.	Generally, digitization limited to one version without consideration of the representation of three dimensional aspects of the original records.

	Preservation Master Files	Production Master Files
	▪ Use of diffuse and/or raking light – digitize using diffuse light to render text and/or writing accurately, and/or digitize using raking light to render the three-dimensionality of the document (folds, creases, embossed seals, etc.). ▪ Digitize documents folded and/or unfolded. ▪ Digitize documents with attachments in place and/or detached as separate documents. ▪ Digitize documents bound and/or unbound. The question that needs to be answered, and there will probably not be a single answer, is how many representations are needed for preservation reformatting to accurately document the original records? The digital library community needs to discuss these issues and arrive at appropriate approaches for different types of originals. One additional comment, originals for which it is considered appropriate to have multiple representations in order to be considered preservation reformatting probably warrant preservation in original form.	

APPENDIX B: Records Handling for Digitization

See NARA's *Preservation Guidelines for Vendors Handling Records and Historical Materials* at http://archives.gov/preservation/technical/vendor-training.html; as well as Appendix E, "*Records Handling for Digitization*," in NARA's 2004 publication of *Technical Guidelines for Digitizing Archival Records for Electronic Access: Creation of Production Master Files – Raster Images*, available at http://archives.gov/preservation/technical/guidelines.pdf.

APPENDIX C: Resources Scope

Introduction -

General Resources –

Moving Theory into Practice, Cornell University Library, available at – http://www.library.cornell.edu/preservation/tutorial

HANDBOOK FOR DIGITAL PROJECTS: A Management Tool for Preservation and Access, Northeast Document Conservation Center, available at – http://nedcc.org/resources/digitalhandbook/dman.pdf

Guides to Quality in Visual Resource Imaging, Digital Library Federation and Research Libraries Group, July 2000, available at – http://www.diglib.org/pubs/dlf091/dlf091.htm *The NINCH Guide to Good Practice in the Digital Representation and Management of Cultural Heritage Materials*, Humanities Advanced Technology and Information Institute, University of Glasgow, and National Initiative for a Networked Cultural Heritage, available at – http://www.ninch.org/guide.pdf

Project Management Outlines –

"NDLP Project Planning Checklist," Library of Congress, available at http://lcweb2.loc.gov/ammem/prjplan.html

"Considerations for Project Management," by Stephen Chapman, *HANDBOOK FOR DIGITAL PROJECTS: A Management Tool for Preservation and Access*, Northeast Document Conservation Center, available at – http://nedcc.org/resources/digitalhandbook/dman.pdf

"Planning an Imaging Project," by Linda Serenson Colet, *Guides to Quality in Visual Resource Imaging*, Digital Library Federation and Research Libraries Group, available at - http://www.diglib.org/pubs/dlf091/dlf091.htm

Bibliographical Center for Research's (BCR) Collaborative Digitization Program, available at http://www.bcr.org/cdp/

Metadata -

Common Metadata Types -

Dublin Core Metadata Initiative - http://dublincore.org/documents/dces/

Official EAD site at the Library of Congress - http://lcweb.loc.gov/ead/

Research Library Group's Best Practices Guidelines for EAD - http://www.oclc.org/programs/ourwork/past/ead/bpg.pdf

Harvard University Library's Digital Repository Services (DRS) User Manual for Data Loading, Version 2.04 – http://hul.harvard.edu/ois/systems/drs/drs_load_manual.pdf

California Digital Library Guidelines for Digital Objects - http://www.cdlib.org/about/publications/CDLObjectStd-2001.pdf

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

Metadata Encoding and Transmission Standard (METS) rights extension schema available at – http://www.loc.gov/standards/rights/METSRights.xsd

Peter B. Hirtle, "Archives or Assets?" - http://www.archivists.org/governance/presidential/hirtle.asp

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

Adrienne Muir, "Copyright and Licensing for Digital Preservation," – http://www.cilip.org.uk/publications/updatemagazine/archive/archive2003/june/update0306c.htm

Karen Coyle, Rights Expression Languages, A Report to the Library of Congress, February 2004, available at – http://www.loc.gov/standards/Coylereport_final1single.pdf

MPEG-21 Overview v.5 contains a discussion on intellectual property and rights at – http://www.chiariglione.org/mpeg/standards/mpeg-21/mpeg-21.htm

Peter Hirtle, "When Works Pass Into the Public Domain in the United States: Copyright Term for Archivists and Librarians," – http://www.copyright.cornell.edu/training/Hirtle_Public_Domain.htm

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

Mary Minow, Library Digitization Projects and Copyright – http://www.llrx.com/features/digitization.htm

NISO Data Dictionary - Technical Metadata for Digital Still Images – http://www.niso.org/

Metadata for Images in XML (MIX) – http://www.loc.gov/standards/mix/

TIFF 6.0 Specification - http://partners.adobe.com/public/developer/en/tiff/TIFF6.pdf

Harvard University Library's Administrative Metadata for Digital Still Images data dictionary – http://preserve.harvard.edu/resources/imagemetadata.pdf

Research Library Group's "Automatic Exposure" Initiative - http://www.oclc.org/programs/ourwork/past/automaticexposure/ae_whitepaper_2003.pdf

Global Digital Format Registry – http://hul.harvard.edu/gdfr

Metadata Encoding Transmission Standard (METS) – http://www.loc.gov/standards/mets/

Flexible and Extensible Digital Object Repository Architecture (FEDORA) – http://www.fedora.info/resources/index.php

Open Archival Information System (OAIS) - http://ssdoo.gsfc.nasa.gov/nost/isoas/overview.html

A Metadata Framework to Support the Preservation of Digital Objects - http://www.oclc.org/research/projects/pmwg/pm_framework.pdf

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