# STILL IMAGE WORKING GROUP

# – GAP ANALYSIS –

## Updated 01/12/2010

Contents

## OBJECTIVE

**The Gap Analysis is intended as a living and evolving document to identify and prioritize those areas of digitization that fall within the scope of this Initiative, and that are: a) not currently defined within existing agency guidelines; or b) not adequately addressed by those guidelines. The Still Image Working group can then make use of this information to better focus our combined efforts, and assist in making informed decisions regarding the allocation of resources and budgets in the most efficient manner. This will benefit all participating organizations while adding to the body of knowledge within the cultural heritage community with regard to digital conversion practices and metrics.**

**The issues described in this document have been reviewed by the Still Image Working Group and have been classified as High, Medium and Low Priority. The prioritization of the ranking alone does not determine whether or not an issue will receive resources and attention to resolve a particular issue. Complexity, availability of resources, and relationship to current digitization projects are just some of the factors that influence the order in which these issues will be actively investigated.**

**As a greater number of gaps are identified and described, they may be further subdivided into topical categories, but in the current version of this document, topics within the scope of the Initiative are categorized only by ranking of perceived priority.**

## IDENTIFIED GAPS – HIGH PRIORITY

### EMBEDDED METADATA

**No.: 001**
**Gap:** Insufficiently Addressed
The Still Image Working Group recently approved an interim guideline for metadata carried in TIFF tags, but this only applies to the TIFF format, and addresses only a limited set of metadata. There is a need for a metadata guideline that will address a broader range of data elements, usage, validation, currency of data, and which can be applied across the range of common image file types.
**Justification:** Metadata encoded in an image file can be used for automated or manual processing of image files, quality assurance, determining digitization properties, rights of usage, analog and digital provenance, as well as identifying and understanding the digital object.

### IMAGE SHARPENING

**No.: 002**
**Gap:** Insufficiently Addressed
The topic of image sharpening is addressed in many published guidelines, but the treatment of the topic is overly general and leaves room for deviation and inconsistency of practice.
**Justification:** Most digitized images require some level of sharpening to produce the most "accurate" digital rendition of the original analog object. Sharpening is one of the major elements determining the perceived quality of an image, but is a complicated process when considering multiple outputs, derivatives, and magnifications. We believe it is possible to establish an objective method to establish image sharpening that is independent of the specific content being imaged and does not rely on the subjective interpretation of the person performing imaging functions.

### QUALITY MANAGEMENT

**No.: 003**
**Gap:** Insufficiently Addressed
While existing agency guidelines touch on aspects of quality assurance (QA) and quality control (QC), there is no comprehensive plan that offers guidance on, and descriptions for a comprehensive quality management plan. Such a plan should discuss and explain topics such an acceptance sampling, sampling models and rates of sampling, differences between QA, QC and metrology, and the risks of simple acceptance sampling when used on complex objects (such as eBooks). There is also a need to identify what can be tested in an automated manner and what requires manual or visual inspection.
**Justification:** Defects are one of the most costly aspects of a manufacturing operation, requiring re-work or increased customer support and jeopardizing customer loyalty. The cost of defects is not as clearly defined in the cultural heritage community as in other fields, but the risk can be even more significant. For instance, the digital copy may be the only existing copy of a unique work, and therefore any defect in digitization cannot be later resolved.

### IMAGE SPECIFICATIONS – METRIC AIMS AND LIMITS

**No.: 004**
**Gap:** Insufficiently Addressed
Existing guidelines provide for such metrics as bit-depth, resolution or pixel dimension, and gamma, but do not provide for other areas of that also directly influence visible and, often time, measurable image quality. Such methods and metrics can be developed using the "Imaging the Digital Imaging Framework" document as a starting point. This gap should be addressed in parallel with the Quality Management plan and the Use Objectives.
**Justification:** Existing standardized metrics for digital imaging performance describe the protocols (i.e., the *how*) for measuring attributes such as resolution, noise, color, and other artifacts. However, they do not provide acceptance criteria on those measurements. There is currently very little guidance on what the aims or limits of those metrics should be. Until such pass/fail criteria are offered, appropriate quality control practices cannot be enabled.

### FOLDOUTS AND INSERTS IN BOUND MATERIALS

**No.: 005**
**Gap:** Not Addressed
Current guidelines do not address workflow processes, imaging standards, or the incorporation of foldouts in imaging bound materials. The term "foldouts" is used generically to represent materials in bound volumes that are of different dimensions from the standard book pages. They may be attached or contained in a book pocket, or other manner of inclusion in the bound volume. Most commonly, oversized paper content is bound to the book and unfolded to view the entire content.
**Justification:** A significant percentage of bound books and serials in a library's collection contain foldouts. In some operations, the foldouts are simply not digitized; in others, the entire volume containing foldouts is excluded. A standard approach to digitization workflow, digitization standards, and metadata (image file and ILS) is needed. Ideally, the look of the foldout should be consistent with that of the rest of the work. While a standard method of presentation would be desirable, it would not be within the scope of this group's charter.

### USE OBJECTIVES - DEFINITIONS

**No.: 006**
**Gap:** Insufficiently Addressed (general)
**Justification:** The Still Image Working Group charter states that "standards will be objectives-based," yet standard definitions of the objectives do not exist. Terms such as "preservation," "access," "surrogate," and "production master" are used with regard to digital imaging practices, but it is not clear: a) if the terms are useful for developing standards and specifications; b) and if they are of use, how they direct the digitization process. Objectives need to be clearly defined, described, and related to clearly defined content to provide rationale for digitization specifications to be produced.

### COLOR ENCODING ACCURACY

**No.: 007**
**Gap:** Not Addressed
**Justification:** Recent test data from digitization service providers and device testing has found a high degree of variability between measures of color encoding relative to color reference standards. In addition, literature on the topic of digital color reproduction is complicated by a variety of measures, methods of measurement, and even the appropriateness of color as a measure of image quality. Common measures include Delta E **(**Delta E 1976, Delta E 1994, Delta E CMC, Delta E 2000) and Delta a*b* 2000.

### COLOR SPACE ENCODING

**No.: 008**
**Gap:** Not Addressed
**Justification:** Related to Gap Number 07 (Color Encoding Accuracy), is determining how to best match the color space encoding to the original materials being digitized, and how to integrate color space encoding practices into digitization production workflows.

### SELECTION CRITERIA FOR MASTER IMAGE FILE FORMAT

**No.: 009**
**Gap:** Insufficiently Addressed. Master file format recommendations are provided, but not an established, formalized process for selecting file format or for testing a given file format against criteria used for ranking.
**Justification:** There are many significant consequences for selecting a given image file format, including, but not limited to: space required to store image data, commonality of a file format and availability of tools, error resiliency, ability to embed metadata within the image file, validation methods and tools, efficient encoding and decoding. Currently, lossless TIFF 6.0 is the de facto standard, but other file formats are in use – both as master image files and as derivatives. Some of these include JPEG 2000, RAW, DNG, JPEG, PNG, etc.

### TRANSMISSIVE IMAGE ANALYSIS TARGETS

**No.: 010**
**Gap:** Insufficiently Addressed.
There is no single target or combination of targets that allow for convenient objective analysis of image performance in a standards-compliant manner.
**Justification:** Targets need to be developed and their use integrated into software to provide comprehensive objective measures of image performance of transmissive content. Measurement of noise is easily compromised by target media.

### OBJECTIVE IMAGE PERFORMANCE ANALYSIS – DATA AND WORKFLOW

**No.: 011**
**Gap:** Insufficiently Addressed
A model needs to be developed to make use of data from image analysis software for Quality Control (QC) and Statistical Process Control (SPC) purposes.
**Justification:** Applications assessing image performance should make that data that is produced available and in a format where tracking, trend analysis, and enable proactive quality measures to be taken.

### SUBJECTIVE IMAGE PERFORMANCE ANALYSIS

**No.: 012**
**Gap:** Insufficiently Addressed
**Justification:** A visual atlas of image defects and severity ratings need to be developed to facilitate a common vocabulary of subjective defects. This should be combined with the effort to develop a full Quality Management plan to guide statistical sampling for defect analysis by visual inspection. Along with the Objective Image Performance Guidelines, this will also assist in determining the causes of poor image quality.

### FULL LIFE-CYCLE QUALITY MANAGEMENT PLAN

**No.: 013**
**Gap:** Insufficiently Addressed
Quality Management (including areas such as Planning, Quality Control, Quality Assessment, and Metrology), should be a component of every phase of the digitization process.
**Justification:** To make effective use of the various tools, applications, and procedures to assess the quality of individual or compound images, a complete Quality Management plan needs to be developed that encompasses the full life-cycle of the digitization process.

## IDENTIFIED GAPS – MEDIUM PRIORITY

### DE-MOSAIC INTERPOLATION AND COLOR SAMPLING

**No.: 001**
**Gap:** Insufficiently Addressed
The real-world quality impact of de-mosaic interpolation has not been addressed in agency guidelines, either as a comparison between devices that interpolate color and those that provide full color sampling, or between different interpolation algorithms.
**Justification:** Experimentation needs to be conducted to determine: a) whether "instant" capture devices provide adequate quality compared to linear array (or full color sampling) devices for established imaging objectives; b) whether there are significant differences in quality between devices using different interpolation algorithms; c) identify/develop targets and methodologies to quickly identify artifact-related problems.

### TILING AND STITCHING FOR OVERSIZE OBJECTS

**No.: 002**
**Gap:** Not Addressed
As object size increases, the price of equipment increases while choice of equipment decreases. Creating composite images through tiling and stitching is becoming a more common method to deal with large size objects. The problem is that no guidelines exist to evaluate the quality of such composite images, nor how they would compare to digital objects created through a single imaging process.
**Justification:** The digitization of materials over a "standard" size is generally given special consideration in guidelines or best practices, but the approach to digitization is fundamentally the same as smaller objects. There is a balance between the smallest significant dimensions of information or significant artifacts against the available technology (and file size). One approach to deal with this would be to take multiple images of the object (taking care to be consistent with perspective and illumination), and then to stitch the multiple images to form a whole. This is commonly performed in medical/scientific imaging where a photomicrography results in very small image areas. While this is a common practice in scientific imaging, our community has not established any guidelines around quality of stitched images, or even identified what measures to use in evaluating image quality.

### ILLUMINANT PRODUCTION AND WORKFLOW ISSUES

**No.: 003**
**Gap:** Not Addressed
**Justification:** The three basic determinants of color are: 1) the properties of the object, 2) the response of the sensor (film, digital array, eyes), 3) the properties of the illuminant. We currently use illuminants listed as standard (D50, D65, etc.) or of a listed color temperature, or in some cases, illuminants of unknown characteristics (cool white fluorescent). The question is how important is it

to standardize on an illuminant for digitization and viewing, and whether information on the properties of those illuminants should be measured and recorded, and if so, to what level of detail.

### GUIDELINES FOR ALIASING PREVENTION

**No.: 004**
**Gap:** Insufficiently Addressed
**Justification:** Because digital imaging systems sample at uniformly periodic distances, an interaction with the image content of a collection is possible that causes aliasing artifacts. While the theory of this is well understood, reliably measuring and visually recognizing aliasing can be difficult. Aliasing often manifests itself upon display as a moiré-like artifact. Not as well known recognized though is the artificially high measured noise it can introduce when digitizing B&W silver halide film. Better measurement protocols and cautionary prevention guidelines are needed to manage the introduction of aliasing into digital images.

### GUIDELINES FOR NEWTON'S RINGS

**No.: 005**
**Gap:** Insufficiently Addressed
**Justification:** Guidelines on the prevention and management of Newton's rings in workflow environments is crucial when digitizing collections where contact with glass surfaces is likely. Many current solutions are simply not suited to fragile collections or amenable to conservator consent. Dialogues with conservators on such issues are also necessary to arrive at low-risk solutions such as vacuum or static hold downs. This is an especially troublesome problem for this community since most collection content is not flat and requires some manner of mechanical flattening for high quality digitization.

### HUMAN VISUAL SYSTEM (HVS) CONSIDERATIONS IN REPORTING AND ANALYZING NOISE

**No.: 006**
**Gap:** Insufficiently Addressed
ISO 15739 does not have a standard for visual noise measures, only an informative approach in Annex C. The initial approach provided in the current version of this standard is quite limited with respect to perceived noise.
**Justification:** In the majority of cases, the primary interest in image quality is the viewing quality judged by the observer of the digitized image output. The HVS has a unique and complex response to the spatial structure of noise in images. Simply following existing standards will not allow a sufficient analysis of noise in this respect.

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### LIGHTING GEOMETRY

**No.: 007**
**Gap:** Not Addressed
**Justification:** The angle and level of diffusion of incident light for reflective imaging can have a profound influence on the resultant image. Considerations such as gloss, flatness, paper "tooth," and desired object representation all play a role in making decisions on lighting. To a lesser extent (and lower in priority), this lighting geometry is also a factor in the imaging of transmissive objects. Many standards also require specific lighting conditions when performing image performance assessments.

### "VISUALLY LOSSLESS" IMAGE DEFINITION AND CONDITIONS

**No.: 008**
**Gap:** Not Addressed
The concept of "visually lossless" is generally used in the context of image compression, with the compressed version of a file "visually identical" to the uncompressed or less compressed version.
**Justification:** The concept of "visually lossless" had definite value with regard to file compression, may also have value in determining imaging requirements, but the value depends upon a strict and uniform description of the term and a full description of the environmental viewing conditions.

## IDENTIFIED GAPS – LOW PRIORITY

### GEOMETRIC DISTORTION – CURVATURE CORRECTION

**No.: 001**
**Gap:** Not Addressed
Current guidelines address methods to capture the maximum amount of content in the gutter of bound materials at the highest quality. What is not addressed is how to digitally represent the shape and perspective of a page as it was created before binding. To achieve this, three-dimensional mapping must be performed to apply a geometric correction of the image and reconstruct as a rectangular page without any distortion of image information (text or graphics) that occupy the area of page radius.
**Justification:** For historical scanning efforts, this topic has not been considered of great concern. Some books are disbound, sheet-feed scanned, and re-bound to deal with this problem if the books are not "rare" and there are not political limitations. In most cases, the distortion of text and graphics in the gutter is simply accepted as an artifact of the scanning process – even if it degrades optical character recognition (OCR) along a linear (y-axis) orientation. If an objective is to be able to re-create a scanned object (round-tripping, print on demand (POD)), three-dimensional information must be obtained to allow the mathematical geometric reconstruction of the page image to result in pages as they were created and appeared prior to binding. There are several methods to overlay optical information to support this type of reconstruction.

### PARALLELISM MISALIGNMENT – PARALLELOGRAMS VS. RECTANGULAR IMAGES

**No.: 002**
**Gap:** Not Addressed
It appears that the effort to establish and maintain a parallel plane between the object to be scanned and the sensor plane, there does not seem to be either instructive information on establishing this relationship or what level of deviation from a rectangular shape is acceptable.
**Justification:** Although not all objects can be positioned in a manner where the object is parallel to the sensor plane, it is generally of great importance to do so. Deviation from parallelism has adverse effect on resolution, perspective, possible lighting/reflection issues, and the effort and quality considerations involved in correct in post processing correction. It should be noted that curators may request imaging of object at oblique angles to provide a more three-dimensional representation of a work.

### DEPTH OF FIELD (DOF) AND OPTIMUM APERTURE

**No.: 003**
**Gap:** Not Addressed
While there is documentation on determining the resolution of an image, and guidelines on what that resolution should be, there is nothing addressing the issue of Depth of Field (DOF) and resolution.
**Justification:** While the scope of the Still Image Working Group states that it is to "concentrate on digitally representing the two-dimensional aspect of the object," much of what we digitize has a significant three-dimensional aspect. I'm primarily referring to bound volumes. When the combination of cradle angle and volume thickness results in a "deep gutter," depth of field becomes a significant issue.
Decreasing the size of the lens aperture will increase the DOF, but creates a larger circle of confusion due to lens diffraction. For each lens, there is an optimum aperture. Generally the optimum aperture is at a relatively large aperture; at odds with the need for large DOF. And stopping down to increase DOF increases length of exposure, introducing another source of possible image degradation. A standard procedure should be developed and documented to address this need.

### SLANT EDGE MEASURE OF RESOLUTION –REPEATABILITY OF MEASURE/PRECISION

**No.: 004**
**Gap:** Not Addressed
While there are existing agency/institution standards and guidelines for using the Modulation Transfer Function (MTF) to determine resolution and this method is listed as an ISO Standard (ISO 12233), there is no information on how precise this method is and what level of repeatability can be expected.
**Justification:** Without knowing the precision of the method used to determine resolution, we have no way of knowing what we should consider acceptable from an imaging provider, or what level of repletion of measurement is necessary to obtain a representative value. Some very preliminary studies have indicated a range of ± 7%, but a well designed experiment would have to be performed to provide information on causes of variation, degree of variation, frequency, etc.

### MODULATION TRANSFER FUNCTION

**No.: 005**
**Gap:** Not Addressed
**Justification:** This gap is not questioning the value of an MTF-based resolution criterion, but whether a value of 0.10 is the most appropriate for all types of content being imaged, or if any single value is sufficient. Actual results obtained from a variety of imaging devices show significantly different curves along the range of values, with device A possibly having a greater response at 0.10 than device B, but device B being superior at 0.50. It is possible that device A may be superior for text-based content for OCR while device B may be superior for imaging photographic content.

### NOISE CLEANING ARTIFACTS

**No.: 006**
**Gap:** Not Addressed
**Justification:** Image noise or granularity is inherent in any digital image. These noise levels increase as greater speed and enhancement demands are placed on digitizing workflows. To reduce this noise, noise cleaning algorithms are sometimes applied to the digital image, especially for cameras that are likely to be used for consumer or professional photography. When such cameras are adopted for other applications, the user needs to be aware of the types of artifacts that are introduced into the final image. Current noise metrology protocols are insufficient of detecting such behaviors.

### GUIDELINES FOR RAW FILE FORMAT PROCESSING

**No.: 007**
**Gap:** Insufficiently Addressed
**Justification:** Raw file formats have the potential to be an excellent digital archiving solution. Extracting raw image data early in the processing chain gives the greatest rendering flexibility but with greater output variability. Similarly, late data extraction gives less flexibility but with less variability. Since there is no single definition or "tap" point for the data handoff, rendered image variability can be high given the number of image processing choices. Guidelines, on sharpening, tone, & color settings need to be offered to constrain such variability.

### LIGHTING POLARIZATION

**No.: 008**
**Gap:** Not Addressed
**Justification:** As with lighting geometry, polarization of light strongly influences the appearance of a digitized object. The use of polarizing material between light source and object, reflected light and image system, or both can remove or mitigate glare or specular reflections. Their use can change, but not always improve upon desired object representation.