Digital Imaging Framework (Draft)
Part I – Taxonomy of Digital Imaging Performance
Part II – Evaluation and Quality Control of Digital Imaging

Introduction
As described in the Still Image Charter, a key element to our approach to developing guidelines is to describe and document a common foundation of quality metrics to be used in investigating and evaluating the digital objects created through digital imaging.

The following two-part document was developed to satisfy that need. Part I of the document provides 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. Part II of the document builds upon the framework set forth in Part I and provides operational metrics and criteria for evaluating digital image characteristics for purposes of investigation or, when used with specific requirements, for quality control purposes.

Future work of the Still Image Working Group will rely on this document to establish quantitative guidelines using the derivative metrics and evaluation criteria described in this document. The actual values that will be inserted into specific imaging guidelines will depend on the content to be digitized and the objectives for digitization. A description of content and objective categories is under development by the Categories and Objectives Sub-group. This framework document, combined with specified content and objective categories form the foundation of specific imaging guidelines that will follow.

Explanation of Document Features and Layout:
Graphical symbols used in the row labeled "Evaluative Criteria *(units)*" indicate Primary, Secondary and Tertiary measures.

● =Primary
◗ =Secondary
○ =Tertiary

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). For example, while Sampling Rate, Resolution and Sharpening are all listed as Primary measures under SFR, Depth of Focus is listed as a Secondary measure.

The same concept applies within the measurement for a given metric. Again taking SF as an example, Max SFR gain is suggested as the Primary Measure under Sharpening, and Sign of SFR slope as a Secondary Measure. Below the hierarchical tiers are two additional informational tiers. The first provides a listing of related descriptive terms that may be more commonly known to users. Finally, the bottom-most tier provides a list of possible causes of failure related to a particular metric.

Terms may also appear as links. These terms will take the user to the [Glossary of Terms](#) for definitions of technical terms that may not be familiar to all users.

Given that this work represents Phase I of an evolving document, not all aspects of performance characteristics or methods of deriving metrics have been developed. In these cases the abbreviation "TBD" for "to be determined" will be present. These are recognized gaps in our knowledge or in our development of established procedures, and will be more fully described in a forthcoming Gap Analysis Document.

Taxonomy of Digital Imaging Performance – Part I

(Information on evaluation criteria, definitions, related descriptive terms,
and possible causes of failure can be found in Part II)

Foundation Metrics	Signal									Signal-to-Noise Ratio	Noise [1]										
Image Science/ 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	*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)*

[1] 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.

Evaluation and Quality Control of Digital Imaging – Part II

- SIGNAL -

Umbrella Protocol						
	SFR - Spatial Frequency Response – (ISO 12233, ISO 16067-1, ISO 16067-2, ISO 15524) *Definition* : A spatial frequency descriptor of an imaging system's ability to maintain the relative contrast of input stimuli **Related Concept** MTF – Modulation Transfer Function					

Derivative Metrics	Sampling Rate	Resolution	Sharpening	Acutance	Flare	Depth of Focus
	Definition: The spatial frequency of the digital sampling. The reciprocal of the center-to-center distance between closest adjacent pixels	*Definition:* An imaging system's ability to resolve finely spaced detail. The level of spatial detail that can resolved in an image	*Definition* :Amplification of the SFR by means of image processing to achieve sharper appearing images	*Definition*: An objective SFR based metric that is used as a correlate to perceived image sharpness.	*Definition:* a skirty or wide spreading of light.	*Definition:* The distance along the optical axis that remains within acceptable focus.

Evaluation Criteria (*units*) ●=Primary ◗=Secondary ○=tertiary	Sampling Rate	Resolution	Sharpening	Acutance	Flare	Depth of Focus
	●: 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:* unitless ●: 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*	TBD	TBD	◗: distance along the optical axis *Units:* inches, mm.

Related descriptive term	Sampling Rate	Resolution	Sharpening	Acutance	Flare	Depth of Focus
	- Megapixels	– Blurred – Soft – Sharp	– Haloing – Garish looking edges – Over sharpening – Edgy – Sharp	- Sharpness	– Low contrast – Hazy – Soft	TBD

Possible causes of failure	Sampling Rate	Resolution	Sharpening	Acutance	Flare	Depth of Focus
	- 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	- Optical performance exceeds sampling rate	- Dirty lens - Light in lens - Poor quality lens	- poor F-number choice

- SIGNAL -

Umbrella Protocol	OECF – Opto-Electronic Conversion Function (ISO 14545)			
	Definition : Average large area digital response of an electronic imaging device to light stimuli **Related Concepts** TTF – Tonal Transfer Function TRC – Tone Reproduction Curve			

	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 Accuracy *Definition* : The difference between selected physically measured input colors and their intended output rendering from a given color space.
Derivative Metrics				

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 (unit less)	●: 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, ΔE_{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 (ΔE_{a*b*}), *Units (◗):* Delta C, Delta H

Related descriptive term	– Too dark/light – Under/over exposed – No shadow/highlight detail – Clipping – Too little(flat) or too much (snap) contrast	– Too dark/light – Under/over exposed – No shadow/highlight detail – Clipping – Too little(flat) or too much (snap) contrast	– Known white or gray subject matter (paper base, specular reflections) has a color cast	– Over/under saturated colors – Color balance is wrong – Memory colors are not correct - Color Accuracy

Possible causes of failure	–Auto-contrast failures –Inappropriate black/white point calibration – Wrong gamma selection		– Poor auto-white balance algorithm – Bad white /black point calibration – Sparse gray patch balancing	– 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

Evaluation and Quality Control of Digital Imaging

- NOISE –

Umbrella Protocol	– Geometric/Spatial Distortion – *Definition:* The deviation of any imaged point from its intended or aim spatial position relative to the input object.					
Derivative Metrics	**Pincushion/ Barrel** <u>(macro)</u> *Definition* : A change in magnification of an imaged object as a function of field position.	**Regional** <u>(micro)</u> *Definition* : A locally varying deviation in intended spatial position of an imaged object	**Color Misregistration** <u>(micro)</u> *Definition:* color-to-color spatial dislocation of otherwise spatially coincident color features of an imaged object.	**Aliasing** <u>(micro)</u> *Definition* : A sampling effect that leads to spatial frequencies being falsely interpreted as other spatial frequencies	**Spatial SFR uniformity (luminance)** <u>(micro)</u> *Definition* : A difference in luminance SFR as a function of optical field position	**Color Interpolation Errors** <u>(micro)</u> *Definition* : TBD
PASS/FAIL Criteria *(units)* ●=Primary ◗=Secondary ○=tertiary	◗: The amount of distortion derived from a selected position on a field distortion diagram *Units:* % distortion (unitless)	TBD	●: The amount of spatial dislocation between any two selected color channels. *Units:* # pixels, # inches, # mm	◗: SFR response at half-sampling frequency *Units:* % SFR response ○: Integrated SFR area beyond the half-sampling *Units: TBD*	◗: % deviation in SFR response at a selected spatial frequency across the field of view *Units: RMS SFR response Min/Max SFR response*	TBD
Related term	- Pincushion - Barrel - TV distortion	- Wobble	- Colored edges	– Jagged edge transitions – Moiré patterns	- Blurred or soft look near corners of image	- Colored checkerboard patterns - zipper artifacts
Possible causes of failure	Poorly designed optics	Non-uniform	TBD	- Optical performance exceeds sampling rate	TBD	- Piezo movement needs adjustment on *N*-shot cameras.

- NOISE -

	Radiometric Distortion – *Definition:* The deviation of any given spatially imaged point from its aim radiometric value relative to the input object.					
Umbrella Protocol	**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 cross color channel radiometric deviations relative to an identified aim	
Derivative Metrics	Temporal	Fixed Pattern			<u>Color Uniformity</u> (deterministic) *Definition* : A difference in large area uniformity/shading between color channels	<u>Color SFR uniformity</u> (deterministic) *Definition* : The differential spread of light between color channels.
	<u>Random</u> (stochastic) *Definition* : The root mean square deviation (std. deviation) of both temporal and fixed pattern noise for a single color channel	<u>Banding/ Streaking</u> (deterministic) *Definition* : One dimensional patterns	<u>Defects</u> (stochastic) *Definition* : point or clusters of defective or poorly corrected pixels	<u>Uniformity/ Shading</u> (deterministic) *Definition* : a generally low frequency		
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	TBD	TBD	TBD	TBD	TBD
			TBD	TBD	TBD	TBD
Related descriptive term	Temporal noise	- Stripes - Banding -Streaking	TBD	TBD	TBD	– Colored edges – Color Bleed – Fringing
Possible causes of failure	TBD	- Poor sensor calibrations - dust/dirt on sensor	TBD	TBD	TBD	TBD