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JPEG 2000 CODEC Certification Guidance for 1000 ppi Fingerprint Friction Ridge Imagery

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VERSION HISTORY

Date	Activity
05/2015	Original document published
03/2016	Several changes made to improve accuracy of tabled values and clarity of the conformance test procedures.

Disclaimer

Specific hardware and software products identified in this report were used in order to perform the evaluations described in this document. In no case does such identification of any commercial product, trade name, or vender, imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the products and equipment identified are necessarily the best available for the purpose

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TERMS AND DEFINITIONS

Table 1 – Abbreviations

CJIS	Criminal Justice Information Services Division
CODEC	Encoder and Decoder
FBI	Federal Bureau of Investigation
IAI	International Association for Identification
ITL	Information Technology Laboratory
JPEG	Joint Photographic Experts Group – ISO/IEC committee developing standards for image compression
NBIS	NIST Biometric Image Software
NIST	National Institute of Standards and Technology
PGM	Portable Graymap (image) Format
ppi	Pixels per inch
ppmm	Pixels per millimeter
SIVV	Spectral Image Validation/Verification Metric
WSQ	Wavelet Scalar Quantization – algorithm for compression of fingerprint imagery

ABSTRACT

The document describes the procedure by which applications of JPEG 2000 CODECs will be evaluated with respect to conformance to the NIST guidance for compression of 1000 ppi[1] friction ridge images as detailed in NIST Special Publication 500-289 [NIST5]. The document describes the attributes of a set of fingerprint images selected for conformance testing and the rationale for selection of these images based on both examiner assessment of image quality over increasing degrees of JPEG 2000 compression and relative fidelity based on computational metrics described SP 500-289 and supporting studies. The document provides background behind the conformance testing, describes the CODEC pathways to be tested and the metrics used to measure conformance, and provides instructions on how to run the protocol and submit results to NIST for evaluation.

KEYWORDS

Fingerprint lossy compression; lossless compression; 1000 ppi fingerprint imagery; JPEG 2000; latent fingerprints

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[1] ppi = pixels per inch; 1000 ppi equals 39.4 pixels per millimeter (ppmm). Resolution values for fingerprint imagery are specified in ppi throughout this document. This is based on widely used specification guidelines for such imagery and is accepted as common nomenclature within the industry.

1. Background

The criminal justice communities throughout the world exchange fingerprint imagery data primarily in 8-bit gray-scale and at 500 ppi. The Wavelet Scalar Quantization (WSQ) Gray-Scale Fingerprint Image Compression Specification [WSQ] is the de facto standard for the compression of 500 ppi fingerprint imagery. WSQ is a "lossy" compression scheme. Lossy compression algorithms employ data encoding methods which discard (lose) some of the data in the encoding process in order to achieve an aggressive reduction in the size of the data package. Decompressing the resulting compressed data yields content that, while degraded, is similar enough to the original that it remains useful for the intended purpose. WSQ allows users to specify how much compression is to be applied to the fingerprint image at the cost of increasingly greater loss in fingerprint image fidelity.

The WSQ Specification provides lossy compression guidance based on an International Association for Identification (IAI) study [FITZPATRICK] conducted in the early 90's. This study assessed the negative impact of increased data loss (due to higher levels of lossy compression) on forensic fingerprint comparisons, and from the study's findings a policy of WSQ 15:1[2] lossy fingerprint compression was adopted. As a result, conformance testing [WSQ1, WSQ2] has been designed to check adherence to the WSQ Specification and thereby ensure fidelity and admissibility in courts of law for fingerprint images that have been processed by a specific implementation of a WSQ encoder and decoder (CODEC).

Lossless compression is an alternative to lossy compression where compression is applied in such a way as to fully preserve the data content of the source image, thus avoiding any data loss. Lossless compression is typically applied, for example, to latent fingerprint images where image fidelity is critical to maximizing human examiner comparison[3] and submission of evidence. While lossy compression can achieve rates higher than 10:1, lossless compression algorithms are able to achieve compression rates only on the order of 2:1.

Fingerprint technology has continued to evolve and advance since the establishment of the WSQ Specification for 500 ppi images. A new generation of fingerprint capture devices now exist that scan fingerprints at 1000 ppi and greater. The increased image resolution is particularly helpful with forensic comparison of fingerprints; however, this comes at the price of 4X the number of pixels for 1000 ppi. Over this same period of time, JPEG 2000 [JPEG2K] was developed as a standard CODEC to improve on the original JPEG image compression standard's discrete cosine transform-based methodology [JPEG] yielding increases in both data compression and subjective image quality. JPEG 2000 provides additional flexibility in the creation and manipulation of the code-stream and is based on the same family of wavelets as WSQ which is used for fingerprint image compression at 500 ppi. Given the improved performance, greater flexibility, and commodity-level availability of JPEG 2000, it was desirable to migrate from WSQ to the JPEG 2000 standard for use with 1000 ppi fingerprint imagery. This raises the question, "*What should be the guidance for applying JPEG 2000 compression to 1000 ppi fingerprints?*"

In 2013, the National Institute of Standards and Technology (NIST) in partnership with the Federal Bureau of Investigation (FBI) concluded an investigation to develop this guidance. NIST conducted a series of methodical studies based on the framework established by the IAI's approach to WSQ. The NIST investigation resulted in a set of specifications to be used as a normative specification for the compression of 1000 ppi friction ridge imagery. These specifications were published in NIST Special Publication 500-289 [NIST5], and this specification was adopted by the FBI's Advisory Policy Board (APB) in June 2014.

While SP 500-289 provides guidance on the parameters used with JPEG 2000 to compress 1000 ppi fingerprints, it does not address testing for conformance. This document describes a conformance testing methodology to validate JPEG 2000

[2] 15:1 was found to be the average compression ratio using a target bit rate of 0.75 bits per pixel. With WSQ the actual compression ratio may vary with a given target bit rate according to the spatial frequency content of the image.

[3] FBI-sponsored Scientific Working Group for Friction Ridge Analysis, Study and Technology (SWGFAST) standards since August 2001 (http://www.swgfast.org/Documents.html) have mandated lossless image compression for latent print examination casework, but exempted AFIS-related fingerprint and palm-print images from lossless compression requirements. As of March 2015, the Friction Ridge Subcommittee of NIST's Organization of Scientific Area Committees is embracing SWGFAST's existing digital imaging standards and guidelines, but may modify them at a future date.

CODECs to ensure they meet the operational characteristics resulting from the application of parameters defined in NIST SP 500-289 as applied to 1000 ppi friction ridge imagery. This includes compression in both lossy 10:1 and lossless modes. While SP 500-289 also specifies the preferred method for downsampling 1000 ppi friction ridge imagery to 500 ppi, the conformance testing of downsampling is to be described in NIST Special Publication 500-306.

Section 3 describes the key resources supporting this effort; Section 4 presents a framework of the CODEC pathways that are to be tested; Section 5 defines the testing metrics used to evaluate image fidelity and conformance; Section 6 describes testing reports and the criteria to receive certification (from the FBI); and Section 7 documents procedures for participating in this testing.

2. Scope and Applicability

This document covers conformance of JPEG 2000 CODECs to the specification for compression of 1000 ppi friction ridge images as described in NIST Special Publication 500-289 [NIST5]. It excludes elements of the specification relating to the downsampling of 1000 ppi fingerprint images to 500 ppi with subsequent compression according to the WSQ specification [WSQ] for interoperability with legacy fingerprint databases. Conformance to downsampling recommendations will be covered in a separate document to be designated NIST Special Publication 500-306.

3. Key Resources

3.1. Reference Fingerprint Image Set

A carefully selected set of 1000 ppi friction ridge imagery is needed to test implementations of SP 500-289 – specifically to test the proper application of SP 500-289 to a JPEG 2000 CODEC as indicative by measuring the fidelity of resulting images to the original images. To this end, a subset of 30 fingerprint images (listed in Table 2) were selected from NIST special Database 27A (SD27A) [SD27] based on their sensitivity to compression changes as measured by human examiner subjective assessment of image fidelity. Complete details of this procedure are reported in NISTIR-7778 [NIST2]. For each fingerprint image of the selected subset a group of 3 examiners observed each image and found progressive degradation as compression ratios increased from 7:1 to 10:1 to 12:1. Examiner ratings of degradation could take values from one (1), little or no degradation, to four (4), high degree of degradation. The three examiner ratings for each image were combined into a triplet. This monotonic increasing progression of human detectable degradation can be seen across the examiner decision triplets listed in Table 2 below as compression ratio is increased from 7:1 to 12:1.

As will be seen in Section 4, a number of the image fidelity metrics employed in this testing use thresholds based on statistical margins computed between measurements observed at 10:1 and 12:1. This serves to set bounds on a range known to impact relevant image fidelity. Certain tests also identify behavior computed between measurement observations at 7:1 and 10:1, especially in cases where performance of the CODEC exceeds expectations of the test.

Table 2 – Reference Fingerprint Image Set

Image #	Impression Type	Image W	Image H	Image File Name (from SD27A)	Examiner Decision Triplet[4]		
					7:1	10:1	12:1
1	Flat	685	811	109-B109_R04_F13-B114_R03_F13_1000_02P	111	112	122
2	Flat	663	900	007-G007_R01_F11-B115_R08_F14_1000_09P	111	112	122
3	Flat	769	1985	012-G012_R08_F14_1000_06P	111	112	123
4	Flat	784	702	005-G005_R08_F14_1000_07P	111	112	122
5	Flat	570	845	001-G001_R02_F13_1000_02P	111	112	122
6	Flat	525	849	253-U253_R09_F14_1000_10P	123	222	223
7	Flat	779	2021	080-G080_R08_F14_1000_01P	111	112	113
8	Flat	881	806	146-B146_R06_F12_1000_03P	111	114	123
9	Flat	780	2030	199-B199_R01_F11_1000_06P	122	123	222
10	Flat	511	600	106-B106_R08_F14_1000_05P	111	113	122
11	Rolled	1068	1412	086-G086_R09_F14_1000_09	111	112	122
12	Rolled	1017	1211	212-U212_R02_F13_1000_01	111	112	122
13	Rolled	980	1394	004-G004_R08_F14-B121_R07_F14_1000_03	111	112	222
14	Rolled	952	1256	007-G007_R01_F11-B115_R08_F14_1000_09	111	122	223
15	Rolled	737	1285	112-B112_R02_F13_1000_10	111	112	122
16	Rolled	1269	1167	077-G077_R01_F11_1000_01	111	112	222
17	Rolled	958	936	033-G033_R07_F14_1000_06	111	122	222
18	Rolled	786	1201	033-G033_R07_F14_1000_09	111	112	123
19	Rolled	1482	1273	146-B146_R06_F12_1000_03	111	123	223
20	Rolled	715	795	084-G084_R06_F12_1000_10	112	122	222
21	Slap	3237	2037	250-U250_R01_F11_1000_13	111	112	122
22	Slap	3262	1993	012-G012_R08_F14_1000_13	111	112	113
23	Slap	3133	2010	019-G019_R01_F11_1000_14	112	113	122
24	Slap	3147	2026	021-G021_R07_F14_1000_14	111	112	113
25	Slap	3121	1980	027-G027_R06_F12_1000_14	111	112	122
26	Slap	3243	2005	077-G077_R01_F11_1000_13	111	112	133
27	Slap	3147	1998	077-G077_R01_F11_1000_14	111	112	123
28	Slap	3121	2026	080-G080_R08_F14_1000_14	113	123	223
29	Slap	3160	1990	092-G092_R03_F13_1000_14	113	123	223
30	Slap	3090	2001	107-B107_R09_F14-B108_R06_F12_1000_14	111	112	123

3.2. Reference and Supplier's JPEG 2000 CODECs

The goal of this testing is to determine whether the specification in SP 500-289 has been successfully applied to a specific JPEG 2000 CODEC. This not only requires a reference set of fingerprint images, but also a "reference" CODEC to which results from a CODEC under evaluation can be compared. In this document, the organization requesting conformance testing is referred to as the "supplier" and the algorithm they desire to be evaluated is referred to as the "supplier's CODEC." (Note that it is not the supplier's software implementation of a JPEG 2000 CODEC that is shared with NIST, but rather it is the images or compressed files processed by the supplier's CODEC that are submitted.)

NIST used the Open JPEG's [OPENJPEG] implementation version 2.1 to test the guidance in SP 500-289, and the same implementation is used as the reference CODEC in this test suite. The Open JPEG CODEC, with minor modification, has been incorporated into the NIST Biometric Image Software (NBIS) public domain software distribution [NIST1] and is freely available to CODEC suppliers. The reference fingerprint image set has been processed by the NIST reference CODEC and the results are used to compare outputs from the supplier's CODEC under evaluation.

[4] These examiner decisions are from the experimental data collected for NISTIR-7778[NIST4].

4. CODEC Pathways

By definition a CODEC is comprised of two primary functions: encode, 'E', followed by decode, 'D'. In this evaluation we are comparing performance between two CODECs: the reference CODEC, 'R', and the supplier's CODEC, 'S'. Encoders are to be independent of Decoders, and in this testing the interoperability of the two CODECs is evaluated. Table 3 lists the possible native and interoperable combinations of encoders and decoders. All combinations except for the first column (the native reference) is of interest and will be evaluated.

Table 3 – Combinations of Encoders and Decoders

NATIVE		INTEROPERABLE	
$E_R D_R$	$E_S D_S$	$E_R D_S$	$E_S D_R$
Reference Encoder ↓ Reference Decoder	Supplier's Encoder ↓ Supplier's Decoder	Reference Encoder ↓ Supplier's Decoder	Supplier's Encoder ↓ Reference Decoder

Regrouping these combinations for processing efficiencies creates the pathways shown in Figure 1. Here the inputs and outputs are annotated along with the encoders and decoders. The input to the encoders are the reference fingerprint images, which have never been lossy-compressed and are stored in the Portable Graymap Format (PGM) [PGM] format noted as 'P', with file extension "`.pgm`". The reference fingerprint images are referred to as "source" images and are noted as 'P_{SRC}'. The output from the encoders (and input to the decoders) are JPEG 2000 files with extension "`.jp2`" and are noted as 'J' with a subscript corresponding to its parent encoder. For example, a JPEG 2000 file generated by the supplier's encoder is noted, 'J_{E_S}'. The decoders also output PGM files that reflect the changes (and any degradation) to the source image introduced by the specific CODEC pathway. For example, a PGM file containing results from a fingerprint image which has been lossy-compressed using the supplier's encoder and then processed by the reference decoder is noted, '$P_{E_S D_R}$'. While the reference input fingerprint images are referred to as "source" images, the output images from the encoders and decoders are referred to as "processed" images.

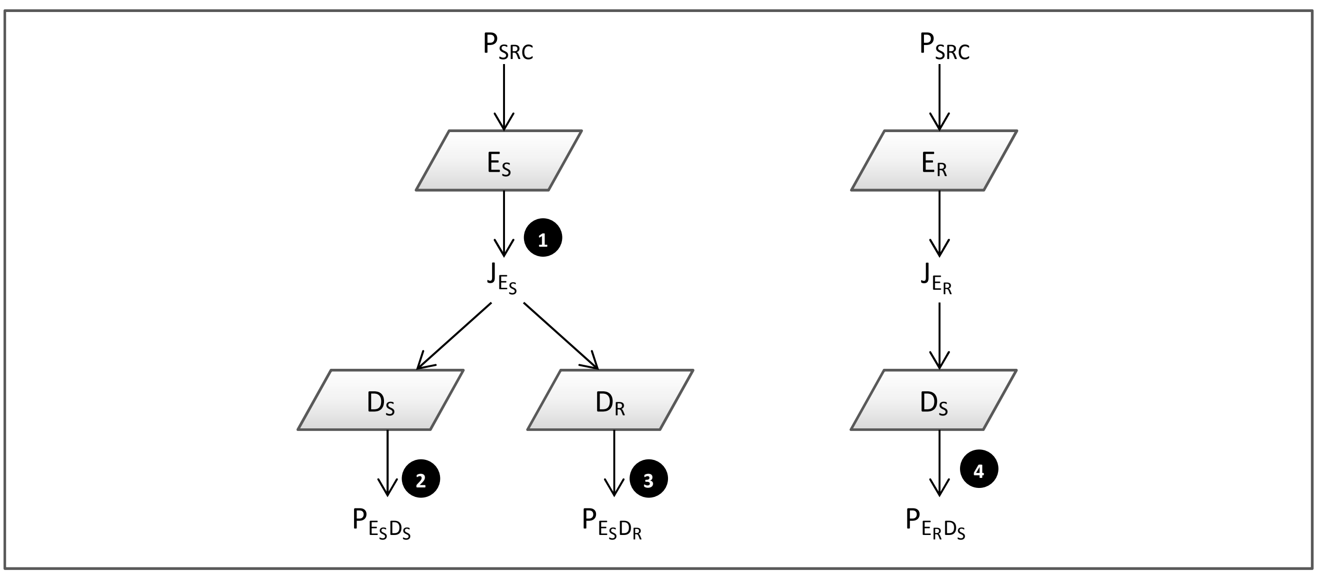

Figure 1 – CODEC Pathways and Input / Output Images

Within these pathways, tests are conducted at four strategic points noted by the circled numbers in the figure above. Table 4 lists the pathway tests along with the images that are compared to assess conformance. The metrics used within each of these tests are documented in Section 5. Note that Test 1 is an encoder-output test, while the other three are decoder-output tests. Also note that Test 3 will be completed by NIST while Tests 1, 2, and 4 will be completed by Suppliers, with the results being sent to NIST for evaluation.

Table 4 – CODEC Pathway Tests

Test	Pathway	Compared
1	E_S	J_{E_S}, J_{E_R}
2	$E_S D_S$	$P_{E_S D_S}$, P_{SRC}
3	$E_S D_R$	$P_{E_S D_R}$, P_{SRC}
4	$E_R D_S$	$P_{E_R D_S}$, P_{SRC}

SP 500-289 provides compression specification of 1000 ppi friction ridge imagery for both lossy 10:1 and lossless modes. It also sets specification on downsampling from 1000 ppi to 500 ppi. The conformance testing for downsampling is addressed in NIST Special Publication 500-306 *Certification Guidance for the downsampling of 1000 ppi Fingerprint Friction Ridge Imagery to 500 ppi*. The testing of both lossy and lossless compression modes follow the same pathways and tests described in Figure 1 and Table 4. The metrics applied to lossy and lossless compression do however differ slightly as described in Section 5.

5. Testing Metrics

Unlike WSQ CODECs, the behavior of JPEG 2000 CODECs varies considerably within a band of "acceptable performance." Whereas WSQ compliance could be assessed very tightly using narrowly defined criteria, such performance precision is not possible with JPEG 2000. For example, for the image-based metrics described below, three different JPEG 2000 CODECs[5] yielded different values when applied to the same test images. As the JPEG 2000 standard itself allows considerable latitude in implementing a CODEC, it would be unfair to define performance criteria tightly to the metric outputs of the NIST (Open JPEG) reference CODEC. Accordingly, for the majority of the image-based metrics used in this testing, performance is assessed by applying a tolerance margin to the measurements made using the reference CODEC. Each image-based metric quantifies a different factor representing change (degradation). Better performing CODECs will generate metrics within a tighter tolerance (or perhaps even exceed the performance of the reference CODEC).

For most of the metrics, conformance is graded at two tolerance thresholds. Those CODECs performing within a primary (tighter) tolerance are granted a grade of “Pass”; those that do not meet this level but are within a secondary (more relaxed) tolerance are granted a grade of “Nominal Pass”; and those that fall outside the secondary tolerance receive a grade of “Fail” for that particular metric. A special designation of “Gold” applies to a Passing supplier’s CODEC that demonstrates improved performance over the reference CODEC. Table 5 lists the possible grade categories.

Table 5 – Metrics Grading Scale

Special Designation	Grade
Gold (Pass)	Desirable performance ***exceeding*** that of reference design
Pass	Acceptable performance meeting reference design
Nominal Pass	Acceptable performance within tolerance of reference design
Fail	Unacceptable performance below reference design tolerances

The metrics used in this testing apply either to encoders or to decoders. The encoder metrics are file-based while the decoder metrics are image-based. Metrics are applied and grades are assigned for performance on each image or file in the suite of test materials. The final grade for each metric is the lowest single grade achieved among the suite of individual measurements regardless of performance on other images or compressed data files in the test dataset. The philosophy here is that for purposes of assessing conformance, the minimum performance is the best indicator and preferred over average or maximum performance.

[5] In addition to Open JPEG, NIST also explored the use of Jasper [JASPER] and Kakadu™ [KAKADU].

5.1. Encoder Metrics

The encoder metrics described below apply to testing both lossy and lossless compression modes.

5.1.1. Compressed File Size

This metric (M_{size}) evaluates the size of the resulting compressed JPEG 2000 image produced by the supplier's encoder (J_{E_S}), determining if the file size (in bytes) is within an acceptable tolerance of that produced by the NIST reference encoder (J_{E_R}). Grades are assessed based on measures set according to Table 6. The thresholds defined in Table 6 are computed across the reference fingerprint image set and listed in Table 7.[6]

Table 6 – Compressed File Size: Measures and Grades

Value Being Graded	$\mathrm{M}_{\mathrm{size}}(J_{E_S})$
Reference Measurement	$\mathrm{M}_{\mathrm{size}}(J_{E_R})$
Primary Tolerance	5 % $\mathrm{M}_{\mathrm{size}}(J_{E_R})$
Secondary Tolerance	10 % $\mathrm{M}_{\mathrm{size}}(J_{E_R})$
Primary Threshold	$\mathrm{M}_{\mathrm{size}}(J_{E_R})$ + Primary Tolerance
Secondary Threshold	$\mathrm{M}_{\mathrm{size}}(J_{E_R})$ + Secondary Tolerance
Gold (Pass)	<= 99 % $\mathrm{M}_{\mathrm{size}}(J_{E_R})$
Pass	<= Primary Threshold
Nominal Pass	<= Secondary Threshold
Fail	> Secondary Threshold

[6] With the notation used in this document, testing metrics (M) are qualified with a subscripted tag (e.g., M_{size}). An italicized metric denotes the metric's value (e.g., M_{size}), while a non-italicized metric denotes the metric's function (e.g., $\mathrm{M}_{\mathrm{size}}(J_{E_R})$).

Table 7 – Lossy Compressed File Size: Reference Image Set Values and Thresholds

Image #	Impression Type	Reference Image File	Reference Measurement	<= Primary Threshold	<= Secondary Threshold
			$M_{size}(J_{E_R})$	Pass	Nominal Pass
1	Flat	109-B109_R04_F13-B114_R03_F13_1000_02P	55 549	58 326	61 104
2	Flat	007-G007_R01_F11-B115_R08_F14_1000_09P	59 666	62 649	65 633
3	Flat	012-G012_R08_F14_1000_06P	152 472	160 096	167 719
4	Flat	005-G005_R08_F14_1000_07P	54 690	57 425	60 159
5	Flat	001-G001_R02_F13_1000_02P	48 077	50 481	52 885
6	Flat	253-U253_R09_F14_1000_10P	44 534	46 761	48 987
7	Flat	080-G080_R08_F14_1000_01P	157 176	165 035	172 894
8	Flat	146-B146_R06_F12_1000_03P	70 994	74 544	78 093
9	Flat	199-B199_R01_F11_1000_06P	158 246	166 158	174 071
10	Flat	106-B106_R08_F14_1000_05P	30 652	32 185	33 717
11	Rolled	086-G086_R09_F14_1000_09	150 757	158 295	165 833
12	Rolled	212-U212_R02_F13_1000_01	123 152	129 310	135 467
13	Rolled	004-G004_R08_F14-B121_R07_F14_1000_03	136 491	143 316	150 140
14	Rolled	007-G007_R01_F11-B115_R08_F14_1000_09	119 490	125 465	131 439
15	Rolled	112-B112_R02_F13_1000_10	94 719	99 455	104 191
16	Rolled	077-G077_R01_F11_1000_01	147 806	155 196	162 587
17	Rolled	033-G033_R07_F14_1000_06	89 311	93 777	98 242
18	Rolled	033-G033_R07_F14_1000_09	94 200	98 910	103 620
19	Rolled	146-B146_R06_F12_1000_03	188 610	198 041	207 471
20	Rolled	084-G084_R06_F12_1000_10	56 843	59 685	62 527
21	Slap	250-U250_R01_F11_1000_13	659 362	692 330	725 298
22	Slap	012-G012_R08_F14_1000_13	649 973	682 472	714 970
23	Slap	019-G019_R01_F11_1000_14	629 569	661 047	692 526
24	Slap	021-G021_R07_F14_1000_14	637 312	669 178	701 043
25	Slap	027-G027_R06_F12_1000_14	617 921	648 817	679 713
26	Slap	077-G077_R01_F11_1000_13	650 149	682 656	715 164
27	Slap	077-G077_R01_F11_1000_14	628 638	660 070	691 502
28	Slap	080-G080_R08_F14_1000_14	632 302	663 917	695 532
29	Slap	092-G092_R03_F13_1000_14	628 783	660 222	691 661
30	Slap	107-B107_R09_F14-B108_R06_F12_1000_14	618 222	649 133	680 044

Table 8 – Lossless Compressed File Size: Reference Image Set Values and Thresholds

Image #	Impression Type	Reference Image File	Reference Measurement	<= Primary Threshold	<= Secondary Threshold
			$M_{size}(J_{E_R})$	Pass	Nominal Pass
1	Flat	109-B109_R04_F13-B114_R03_F13_1000_02P	348 620	366 051	383 482
2	Flat	007-G007_R01_F11-B115_R08_F14_1000_09P	327 584	343 963	360 342
3	Flat	012-G012_R08_F14_1000_06P	941 407	988 477	1 035 548
4	Flat	005-G005_R08_F14_1000_07P	240 406	252 426	264 447
5	Flat	001-G001_R02_F13_1000_02P	284 707	298 942	313 178
6	Flat	253-U253_R09_F14_1000_10P	270 099	283 604	297 109
7	Flat	080-G080_R08_F14_1000_01P	987 530	1 036 907	1 086 283
8	Flat	146-B146_R06_F12_1000_03P	394 332	414 049	433 765
9	Flat	199-B199_R01_F11_1000_06P	1 000 344	1 050 361	1 100 378
10	Flat	106-B106_R08_F14_1000_05P	170 093	178 598	187 102
11	Rolled	086-G086_R09_F14_1000_09	1 038 988	1 090 937	1 142 887
12	Rolled	212-U212_R02_F13_1000_01	859 394	902 364	945 333
13	Rolled	004-G004_R08_F14-B121_R07_F14_1000_03	943 847	991 039	1 038 232
14	Rolled	007-G007_R01_F11-B115_R08_F14_1000_09	812 364	852 982	893 600
15	Rolled	112-B112_R02_F13_1000_10	614 407	645 127	675 848
16	Rolled	077-G077_R01_F11_1000_01	926 199	972 509	1 018 819
17	Rolled	033-G033_R07_F14_1000_06	601 693	631 778	661 862
18	Rolled	033-G033_R07_F14_1000_09	675 887	709 681	743 476
19	Rolled	146-B146_R06_F12_1000_03	1 208 246	1 268 658	1 329 071
20	Rolled	084-G084_R06_F12_1000_10	366 996	385 346	403 696
21	Slap	250-U250_R01_F11_1000_13	3 595 842	3 775 634	3 955 426
22	Slap	012-G012_R08_F14_1000_13	3 489 680	3 664 164	3 838 648
23	Slap	019-G019_R01_F11_1000_14	3 666 932	3 850 279	4 033 625
24	Slap	021-G021_R07_F14_1000_14	3 798 171	3 988 080	4 177 988
25	Slap	027-G027_R06_F12_1000_14	3 609 566	3 790 044	3 970 523
26	Slap	077-G077_R01_F11_1000_13	3 485 079	3 659 333	3 833 587
27	Slap	077-G077_R01_F11_1000_14	3 537 082	3 713 936	3 890 790
28	Slap	080-G080_R08_F14_1000_14	3 776 849	3 965 691	4 154 534
29	Slap	092-G092_R03_F13_1000_14	3 528 289	3 704 703	3 881 118
30	Slap	107-B107_R09_F14-B108_R06_F12_1000_14	3 599 640	3 779 622	3959 604

5.1.2. Compressed File Structure and Metadata

This metric (M_{struct}) evaluates the content of the JPEG 2000 file (J_{E_S}) produced by the supplier's encoder. The compressed JPEG 2000 files must be strictly structured and populated with metadata as specified by

Table 10. Grades (in this case only a grade of Pass or Fail) are assessed based on the criteria in Table 9.

Table 9 – Compressed File Structure and Metadata – Grades

Pass	$M_{struct}(J_{E_S})$, Criteria in Table 10 strictly met
Fail	$M_{struct}(J_{E_S})$, Criteria in Table 10 is not strictly met

Table 10 – Compressed File Structure and Metadata – Criteria

JPEG 2000 Box / Data Field	Value	Size (Bytes)	Hexadecimal
JPEG2000 Signature Box			
Length	12	4	0000 000C
Type	‘jP<SP><SP>‘	4	6A50 2020
Signature	‘<CR><LF><0x87><LF>’	4	0D0A 870A
File Type Box			
Length	20	4	0000 0014
Type	‘ftyp’	4	6674 7970
Brand (BR)	‘jp2<SP>’	4	6A70 3220
Minor Version (MinV)	0	4	0000 0000
Compatibility List (CL)	‘jp2<SP>‘	4	6A70 3220
JP2 Header Box (Superbox)			
Length	71	4	0000 0047
Type	‘jp2h’	4	6A70 3268
Image Header Box			
Length	22	4	0000 0016
Type	‘ihdr’	4	6968 6472
Height	Image Area Height (pixels)	4	
Width	Image Area Width (pixels)	4	
Number of Components (NC)	1	2	0001
Bit Depth minus 1 (BPC)	7 (Corresponds to 8bpp)	1	07
Compression Type (C)	7 (JPEG2000)	1	07
Colorspace Unknown (UnkC)	0	1	00
Intellectual Property (IPR)	0	1	00
Color Specification Box			
Length	15	4	0000 000F
Type	‘colr’	4	636F 6C72
Method (METH)	1 (Enumerated Colorspace)	1	01
Precedence (PREC)	0 (reserved)	1	00
Approximation (APPROX)	0 (reserved)	1	00
Enumerated Colorspace (EnumCS)	17 (grayscale)	4	0000 0011
Resolution Box (Superbox)			
Length	26	4	0000 001A
Type	‘res ‘	4	7265 7320
Capture Resolution Box			
Length	18	4	0000 0012
Type	‘resc’	4	7265 7363
Vertical Capture Resolution Numerator (VRcN)	39 370[7]	2	99CA
Vertical Capture Resolution Denominator (VRcD)	1	2	0001
Horizontal Capture Resolution Numerator (HRcN)	39 370[7]	2	99CA
Horizontal Capture Resolution Denominator (HRcD)	1	2	0001
Vertical Capture Resolution Exponent (VRdE)	0	1	00
Horizontal Capture Resolution Exponent (HRdE)	0	1	00
Contiguous Codestream Box	See section 4.1 of [NIST3]		
Identification and MetaData Box (Comment)			
Marker Code	COM	2	FF64
Comment Length (Lcom)	104	2	0068
Registration Value (Rcom)	1 (ISO/IEC 8859-15 data)	2	0001
Comment Contents	(see section 5.1.3)	100	

[7] Values for VRcN and HrcN are specified here in pixels per meter according to [JPEG2K]. A value of 39 370 corresponds to 1000 pixels per inch.

5.1.3. Encoder Identification

The Identification and Metadata Box is a special purpose comment box that can accommodate up to 100 bytes of structured ISO/IEC 8859-15 [ISO/IEC99] data. This data, also referred to as "comment contents," is used for certification and identification. The structure of the data is described in Table 11 along with sample identification data. The actual identification data must be obtained from NIST on a per-implementation basis. See Section 7 for information on how to obtain supplier identification data needed for this field.

Table 11 – Identification and Metadata Structure

Data Segment Description	Start Position	Length	Example Contents
Encoder Identification Tag	0	7	'EncID: '
Encoder Identification Data	7	20	'CERT-SUBMISSION-0000'
Reserved Block Tag	27	8	' Resvd: '
Reserved Block Data	35	65	'41ab87823014dcb19113dfcd0902c569265270861a7f2cbdff148a38cc260675 '

5.2. Decoder Metrics

The decoder metrics used in this testing are all image-based analyses. All the decoder metrics in this section apply to lossy compression, while only the first two (Image Pixel Dimension, and Altered Pixel Count) are applicable to evaluate the lossless compression mode.

5.2.1. Image Pixel Dimensions

This metric (M_{dim}) evaluates the pixel dimensions of a processed image fingerprint image after it has gone through an encoder plus decoder pathway (e.g., $P_{E_S D_R}$). The number of pixel columns and rows must be the same as that of the source reference fingerprint image, P_{SRC}. Grades (in this case only a grade of Pass) are assessed based on the criteria in Table 12. The values of the pixel dimensions associated with the reference fingerprint image set are listed in Table 2.

Table 12 – Image Pixel Dimension – Grades

Pass	Pixel dimensions are the same, e.g., $M_{dim}(P_{E_S D_R}, P_{SRC})$
Fail	Pixel dimension are different

5.2.2. Altered Pixel Count

This metric ($M_{altered}$) evaluates how many pixels have been altered in a processed fingerprint image after it has gone through an encoder plus decoder pathway (e.g., $P_{E_SD_S}$). The processed image pixels are compared with those in the source reference fingerprint image (P_{SRC}) and each pixel changed is tallied.

5.2.2.1. Altered Pixel Count (for Lossy Compression)

Given a source image, $\boldsymbol{I}^{\emptyset}$ (i.e., P_{SRC}), and the corresponding processed image, $\boldsymbol{I}^{\delta}$ (e.g., $P_{E_SD_S}$), the pixel values of the difference image, ***D***, can be computed as

$$D_{i,j} = |I^{\emptyset}_{i,j} - I^{\delta}_{i,j}| \ , \qquad (1)$$

where *i = 1..R*, and *j = 1..C*, *R* = number of pixel rows and *C* = number of pixel columns.

Given the difference image, ***D***, we construct a bi-level image, ***B***, to which we assign binary values as

$$B_{i,j} = \begin{cases} 0 & D_{i,j} = 0 \\ 1 & D_{i,j} \neq 0 \end{cases} . \qquad (2)$$

We then count the total number of changed pixels as

$$M_{altered} = \sum_{i=1}^{R} \sum_{j=1}^{C} B_{i,j} \ . \qquad (3)$$

The tolerances used for this metric are based on a margin computed between measurements made at both 10:1 and 12:1 using the NIST reference CODEC. (Recall the earlier discussion in Section 3.1 that human examiners observed forensically-relevant degradation between these two compression levels when the reference fingerprint image set was used.) In this case the total altered pixels from a processed image (e.g., $P_{E_SD_S}$) are compared to a margin computed as the difference between the total altered pixels from its source image (P_{SRC}) processed through the pathway of the reference encoder and reference decoder ($P_{E_RD_R}$) using the two compression levels 12:1 and 10:1. In the example used here, we are evaluating a processed image having gone through the pathway of the supplier's encoder and supplier's decoder (E_sD_s). Grades are assessed based on measures set according to Table 13. The thresholds defined in Table 13 are computed across the reference fingerprint image set and listed in Table 14.

Table 13 – Altered Pixel Count (Lossy): Measures and Grades

Value Being Graded (e.g.)	$M_{altered}$(10:1, $P_{E_SD_S}$, P_{SRC})
Reference Measurement @ 10:1	$M_{altered}$(10:1, $P_{E_RD_R}$, P_{SRC})
Reference Measurement @ 12:1	$M_{altered}$(12:1, $P_{E_RD_R}$, P_{SRC})
Margin	$M_{altered}$(12:1, $P_{E_RD_R}$, P_{SRC}) - $M_{altered}$(10:1, $P_{E_RD_R}$, P_{SRC})
Primary Tolerance	25 % Margin
Secondary Tolerance	50 % Margin
Primary Threshold	$M_{altered}$(10:1, $P_{E_RD_R}$, P_{SRC}) + Primary Tolerance
Secondary Threshold	$M_{altered}$(10:1, $P_{E_RD_R}$, P_{SRC}) + Secondary Tolerance
Gold (Pass)	< $M_{altered}$(10:1, $P_{E_RD_R}$, P_{SRC})
Pass	<= Primary Threshold
Nominal Pass	<= Secondary Threshold
Fail	> Secondary Threshold

Table 14 – Altered Pixel Count (Lossy): Reference Image Set Values and Thresholds

Image #	Impression Type	Reference Image File	Reference Measurements		<= Primary Threshold	<= Secondary Threshold
			10:1	12:1	Pass	Nominal Pass
1	Flat	109-B109_R04_F13-B114_R03_F13_1000_02P	492 891	496 090	493 691	494 491
2	Flat	007-G007_R01_F11-B115_R08_F14_1000_09P	527 685	536 196	529 813	531 941
3	Flat	012-G012_R08_F14_1000_06P	1 389 091	1 401 674	1 392 237	1 395 383
4	Flat	005-G005_R08_F14_1000_07P	425 967	437 705	428 902	431 836
5	Flat	001-G001_R02_F13_1000_02P	438 293	443 489	439 592	440 891
6	Flat	253-U253_R09_F14_1000_10P	404 080	408 136	405 094	406 108
7	Flat	080-G080_R08_F14_1000_01P	1 448 913	1 460 429	1 451 792	1 454 671
8	Flat	146-B146_R06_F12_1000_03P	632 253	642 061	634 705	637 157
9	Flat	199-B199_R01_F11_1000_06P	1 452 006	1 463 816	1 454 959	1 457 911
10	Flat	106-B106_R08_F14_1000_05P	272 540	276 615	273 559	274 578
11	Rolled	086-G086_R09_F14_1000_09	1 415 594	1 422 931	1 417 428	1 419 263
12	Rolled	212-U212_R02_F13_1000_01	1 162 434	1 168 981	1 164 071	1 165 708
13	Rolled	004-G004_R08_F14-B121_R07_F14_1000_03	1 284 401	1 290 543	1 285 937	1 287 472
14	Rolled	007-G007_R01_F11-B115_R08_F14_1000_09	1 121 648	1 126 976	1 122 980	1 124 312
15	Rolled	112-B112_R02_F13_1000_10	877 573	882 286	878 751	879 930
16	Rolled	077-G077_R01_F11_1000_01	1 362 492	1 374 763	1 365 560	1 368 628
17	Rolled	033-G033_R07_F14_1000_06	839 273	844 185	840 501	841 729
18	Rolled	033-G033_R07_F14_1000_09	894 666	899 365	895 841	897 016
19	Rolled	146-B146_R06_F12_1000_03	1 748 298	1 759 771	1 751 166	1 754 035
20	Rolled	084-G084_R06_F12_1000_10	528 401	531 239	529 111	529 820
21	Slap	250-U250_R01_F11_1000_13	5 644 636	5 716 121	5 662 507	5 680 379
22	Slap	012-G012_R08_F14_1000_13	5 511 548	5 586 839	5 530 371	5 549 194
23	Slap	019-G019_R01_F11_1000_14	5 610 869	5 679 027	5 627 909	5 644 948
24	Slap	021-G021_R07_F14_1000_14	5 706 003	5 767 504	5 721 378	5 736 754
25	Slap	027-G027_R06_F12_1000_14	5 477 436	5 544 750	5 494 265	5 511 093
26	Slap	077-G077_R01_F11_1000_13	5 529 207	5 599 526	5 546 787	5 564 367
27	Slap	077-G077_R01_F11_1000_14	5 508 070	5 566 641	5 522 713	5 537 356
28	Slap	080-G080_R08_F14_1000_14	5 692 127	5 748 801	5 706 296	5 720 464
29	Slap	092-G092_R03_F13_1000_14	5 509 432	5 565 287	5 523 396	5 537 360
30	Slap	107-B107_R09_F14-B108_R06_F12_1000_14	5 484 471	5 550 742	5 501 039	5 517 607

5.2.2.2. Altered Pixel Count (for Lossless Compression)

The criteria for evaluating lossless compression in regards to altered image pixels are straight forward. For the lossless mode of a supplier's CODEC to Pass there must be zero altered pixels between the source image (P_{SRC}) and the processed image (e.g., $P_{E_S D_S}$).

Table 15 – Altered Pixel Count (Lossless) – Grades

Pass	e.g., $M_{altered}(P_{SRC}, P_{E_S D_S})$ must equal 0
Fail	$M_{altered}(P_{SRC}, P_{E_S D_S})$ does not equal 0

5.2.3. Peak Pixel Difference

This metric (M_{peak}) evaluates the pixel incurring the maximum gray level change comparing a processed image (e.g., $P_{E_S D_S}$) to its source image (P_{SRC}). Given the absolute image difference, ***D***, from equation (1), the peak difference is then

$$M_{peak} = \max(D_{i,j}) \quad (4)$$

The tolerance used for this metric is based on a margin computed between measurements made at both 10:1 and 12:1 using the NIST reference CODEC. In this case the peak pixel difference from a processed image (e.g., $P_{E_S D_S}$) is compared to the peak pixel difference from its source image (P_{SRC}) processed through the pathway of the reference encoder and reference decoder ($P_{E_R D_R}$) using 12:1 compression. For a supplier's CODEC to Pass the peak pixel difference of its processed image must be less than or equal to the reference measurement at 12:1. Grades are assessed based on measures set according to Table 16. The threshold defined in Table 16 is computed across the reference fingerprint image set and listed in Table 17.

Table 16 – Peak Pixel Difference: Measures and Grades

Value Being Graded (e.g.)	$M_{peak}(10{:}1, P_{E_S D_S}, P_{SRC})$
Reference Measurement @ 10:1	$M_{peak}(10{:}1, P_{E_R D_R}, P_{SRC})$
Reference Measurement @ 12:1	$M_{peak}(12{:}1, P_{E_R D_R}, P_{SRC})$
Primary Threshold	$M_{peak}(12{:}1, P_{E_R D_R}, P_{SRC})$
Pass	<= Primary Threshold
Fail	> Primary Threshold

Table 17 – Peak Pixel Difference: Reference Image Set Values and Threshold

Image #	Impression Type	Reference Image File	Reference Measurements		<= Primary Threshold
			10:1	12:1	Pass
1	Flat	109-B109_R04_F13-B114_R03_F13_1000_02P	49	55	55
2	Flat	007-G007_R01_F11-B115_R08_F14_1000_09P	25	36	36
3	Flat	012-G012_R08_F14_1000_06P	43	43	43
4	Flat	005-G005_R08_F14_1000_07P	21	21	21
5	Flat	001-G001_R02_F13_1000_02P	30	30	30
6	Flat	253-U253_R09_F14_1000_10P	32	36	36
7	Flat	080-G080_R08_F14_1000_01P	44	53	53
8	Flat	146-B146_R06_F12_1000_03P	24	41	41
9	Flat	199-B199_R01_F11_1000_06P	57	58	58
10	Flat	106-B106_R08_F14_1000_05P	29	30	30
11	Rolled	086-G086_R09_F14_1000_09	54	54	54
12	Rolled	212-U212_R02_F13_1000_01	51	57	57
13	Rolled	004-G004_R08_F14-B121_R07_F14_1000_03	47	58	58
14	Rolled	007-G007_R01_F11-B115_R08_F14_1000_09	46	51	51
15	Rolled	112-B112_R02_F13_1000_10	34	49	49
16	Rolled	077-G077_R01_F11_1000_01	40	40	40
17	Rolled	033-G033_R07_F14_1000_06	46	51	51
18	Rolled	033-G033_R07_F14_1000_09	50	62	62
19	Rolled	146-B146_R06_F12_1000_03	35	43	43
20	Rolled	084-G084_R06_F12_1000_10	32	42	42
21	Slap	250-U250_R01_F11_1000_13	51	51	51
22	Slap	012-G012_R08_F14_1000_13	30	33	33
23	Slap	019-G019_R01_F11_1000_14	35	45	45
24	Slap	021-G021_R07_F14_1000_14	35	48	48
25	Slap	027-G027_R06_F12_1000_14	39	40	40
26	Slap	077-G077_R01_F11_1000_13	24	30	30
27	Slap	077-G077_R01_F11_1000_14	29	40	40
28	Slap	080-G080_R08_F14_1000_14	47	47	47
29	Slap	092-G092_R03_F13_1000_14	31	41	41
30	Slap	107-B107_R09_F14-B108_R06_F12_1000_14	29	38	38

5.2.4. Image Mean Squared Difference

This metric (M_{MSD}) uses the Image Mean Squared Difference (MSD) - a commonly used image fidelity attribute - to evaluate the amount of gray level pixel change across the entire processed fingerprint image after it has gone through an encoder plus decoder pathway (e.g., $P_{E_S D_S}$). Given a source image, $\boldsymbol{I}^{\emptyset}$ (i.e., P_{SRC}), and a processed image, $\boldsymbol{I}^{\delta}$(e.g., $P_{E_S D_S}$), the image mean squared difference is defined as

$$M_{MSD} = \frac{\sum_{i=1}^{R} \sum_{j=1}^{C} \left(I_{i,j}^{\emptyset} - I_{i,j}^{\delta}\right)^2}{RC} \ , \qquad (5)$$

where *i* and *j* are indices to image pixels, and *R* and *C* are numbers of image rows and columns, respectively. Note that the source image and processed image must be equal in dimensions in order to apply this metric.

The tolerances used for this metric are based on a margin computed between measurements made at both 10:1 and 12:1 using the NIST reference CODEC. In this case the MSD from a processed image (e.g., $P_{E_S D_S}$) are compared to a margin computed as the difference between the MSD from its source image (P_{SRC}) processed through the pathway of the reference encoder and reference decoder ($P_{E_R D_R}$) using the two compression levels 12:1 and 10:1. In the example used here, we are evaluating a processed image having gone through the pathway of the supplier's encoder and supplier's decoder ($E_s D_s$). Grades are assessed based on measures set according to Table 18. The thresholds defined in Table 18 are computed across the reference fingerprint image set and listed in Table 19.

Table 18 – Image Mean Squared Difference: Measures and Grades

Value Being Graded (e.g.)	M_{MSD}(10:1, $P_{E_S D_S}$, P_{SRC})
Reference Measurement @ 10:1	M_{MSD}(10:1, $P_{E_R D_R}$, P_{SRC})
Reference Measurement @ 12:1	M_{MSD}(12:1, $P_{E_R D_R}$, P_{SRC})
Margin	M_{MSD}(12:1, $P_{E_R D_R}$, P_{SRC}) – M_{MSD}(10:1, $P_{E_R D_R}$, P_{SRC})
Primary Tolerance	25 % Margin
Secondary Tolerance	50 % Margin
Primary Threshold	M_{MSD}(10:1, $P_{E_R D_R}$, P_{SRC}) + Primary Tolerance
Secondary Threshold	M_{MSD}(10:1, $P_{E_R D_R}$, P_{SRC}) + Secondary Tolerance
Gold (Pass)	< M_{MSD}(10:1, $P_{E_R D_R}$, P_{SRC})
Pass	<= Primary Threshold
Nominal Pass	<= Secondary Threshold
Fail	> Secondary Threshold

Table 19 – Image Mean Squared Difference: Reference Image Set Values and Thresholds

Image #	Impression Type	Reference Image File	Reference Measurements		<= Primary Threshold	<= Secondary Threshold
			10:1	12:1	Pass	Nominal Pass
1	Flat	109-B109_R04_F13-B114_R03_F13_1000_02P	36.006	46.140	38.539	41.073
2	Flat	007-G007_R01_F11-B115_R08_F14_1000_09P	13.672	18.085	14.775	15.879
3	Flat	012-G012_R08_F14_1000_06P	23.716	28.761	24.977	26.239
4	Flat	005-G005_R08_F14_1000_07P	5.498	6.999	5.873	6.248
5	Flat	001-G001_R02_F13_1000_02P	22.684	28.170	24.055	25.427
6	Flat	253-U253_R09_F14_1000_10P	20.317	25.461	21.603	22.889
7	Flat	080-G080_R08_F14_1000_01P	30.370	37.285	32.099	33.828
8	Flat	146-B146_R06_F12_1000_03P	14.601	19.149	15.738	16.875
9	Flat	199-B199_R01_F11_1000_06P	30.775	36.927	32.313	33.851
10	Flat	106-B106_R08_F14_1000_05P	16.377	21.502	17.658	18.940
11	Rolled	086-G086_R09_F14_1000_09	48.109	58.848	50.794	53.478
12	Rolled	212-U212_R02_F13_1000_01	60.055	74.564	63.682	67.309
13	Rolled	004-G004_R08_F14-B121_R07_F14_1000_03	52.049	63.318	54.867	57.684
14	Rolled	007-G007_R01_F11-B115_R08_F14_1000_09	46.694	57.191	49.319	51.943
15	Rolled	112-B112_R02_F13_1000_10	32.683	40.854	34.725	36.768
16	Rolled	077-G077_R01_F11_1000_01	27.394	33.178	28.840	30.286
17	Rolled	033-G033_R07_F14_1000_06	44.610	55.378	47.302	49.994
18	Rolled	033-G033_R07_F14_1000_09	68.898	85.748	73.110	77.323
19	Rolled	146-B146_R06_F12_1000_03	32.070	38.683	33.723	35.376
20	Rolled	084-G084_R06_F12_1000_10	34.788	44.083	37.112	39.436
21	Slap	250-U250_R01_F11_1000_13	15.632	20.604	16.875	18.118
22	Slap	012-G012_R08_F14_1000_13	10.838	13.516	11.507	12.177
23	Slap	019-G019_R01_F11_1000_14	18.017	22.547	19.150	20.282
24	Slap	021-G021_R07_F14_1000_14	19.723	24.674	20.961	22.199
25	Slap	027-G027_R06_F12_1000_14	16.410	20.615	17.461	18.512
26	Slap	077-G077_R01_F11_1000_13	10.134	12.570	10.743	11.352
27	Slap	077-G077_R01_F11_1000_14	13.028	16.065	13.787	14.547
28	Slap	080-G080_R08_F14_1000_14	21.694	26.949	23.007	24.321
29	Slap	092-G092_R03_F13_1000_14	13.206	16.348	13.991	14.777
30	Slap	107-B107_R09_F14-B108_R06_F12_1000_14	16.685	21.075	17.783	18.880

5.2.5. Spectral Image Root Mean Squared Difference

Developed initially as a method to screen fingerprint databases for non-fingerprint images, segmentation errors, or mislabeled sample rates, the Spectral Image Validation Verification (SIVV) metric [LIBERT] provides a comparatively straightforward method by which to assess the frequency structure of an image. Pairwise display of the SIVV signals of source and lossy compressed images enables summary visualization of the effects of compression across the composition frequency spectrum of the image as shown in Figure 2. As a 1-dimensional representation of a 2-dimensional Fourier spectrum, the SIVV metric applied to a fingerprint image exhibits a peak corresponding to the frequency of the ridge spacing (as shown within the circled region of the figure). In this example, the figure compares the SIVV signals of a source image and a JPEG 2000 processed image. Note the loss or gain of power over various frequencies.

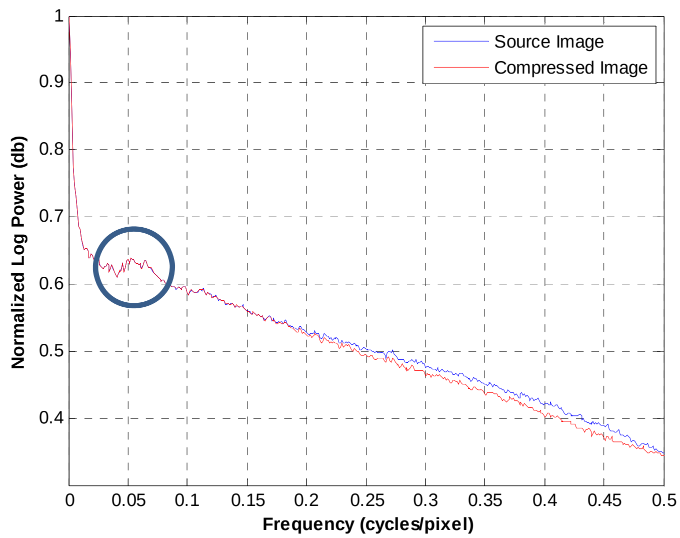

Figure 2 – SIVV signal of a fingerprint image before and after JPEG 2000 lossy compression

The metric (M_{SIVV}) evaluates the amount of image frequency change in a processed fingerprint image after it has gone through an encoder plus decoder pathway (e.g., $P_{E_S D_S}$). The processed image frequency profile is compared with that of the source reference fingerprint image (P_{SRC}).

Given a source image, $\boldsymbol{I}^{\emptyset}$ (i.e., P_{SRC}), and the subsequently processed image, $\boldsymbol{I}^{\delta}$ (e.g., $P_{E_S D_S}$), corresponding SIVV signal vectors are denoted $\mathbf{s}^{\emptyset}$ and $\mathbf{s}^{\delta}$. The Root Mean Squared Difference (RMSD) is used to quantify the total amount of image frequency change between the two signals:

$$M_{SIVV} = \sqrt{\frac{\sum_{i=1}^{n}\left(s_i^{\emptyset} - s_i^{\delta}\right)^2}{n}} \quad , \qquad (6)$$

where $n = |\mathbf{s}^{\emptyset}| = |\mathbf{s}^{\delta}|$ (i.e., the lengths of the signal vectors).

The tolerances used for this metric are based on a margin computed between measurements made at both 10:1 and 12:1 using the NIST reference CODEC. In this case the total change in power at all image frequencies from a processed image (e.g., $P_{E_S D_S}$) are compared to a margin computed as the difference between the total change in power at corresponding frequencies from its source image (P_{SRC}) processed through the pathway of the reference encoder and reference decoder ($P_{E_R D_R}$) using the two compression levels 12:1 and 10:1. In the example used here, we are evaluating a processed image having gone through the pathway of the supplier's encoder and supplier's decoder ($E_s D_s$). Grades are assessed based on measures set according to Table 20. The thresholds defined in Table 20 are computed across the reference fingerprint image set and listed in Table 21.

Table 20 – Spectral Image Root Mean Squared Difference: Measures and Grades

Value Being Graded (e.g.)	M_{SIVV}(10:1, $P_{E_S D_S}$, P_{SRC})
Reference Measurement @ 10:1	M_{SIVV}(10:1, $P_{E_R D_R}$, P_{SRC})
Reference Measurement @ 12:1	M_{SIVV}(12:1, $P_{E_R D_R}$, P_{SRC})
Margin	M_{SIVV}(12:1, $P_{E_R D_R}$, P_{SRC}) – M_{SIVV}(10:1, $P_{E_R D_R}$, P_{SRC})
Primary Tolerance	25 % Margin
Secondary Tolerance	50 % Margin
Primary Threshold	M_{SIVV}(10:1, $P_{E_R D_R}$, P_{SRC}) + Primary Tolerance
Secondary Threshold	M_{SIVV}(10:1, $P_{E_R D_R}$, P_{SRC}) + Secondary Tolerance
Gold (Pass)	< M_{SIVV}(10:1, $P_{E_R D_R}$, P_{SRC})
Pass	<= Primary Threshold
Nominal Pass	<= Secondary Threshold
Fail	> Secondary Threshold

Table 21 – Spectral Image Root Mean Squared Difference: Reference Image Set Values and Thresholds

Image #	Impression Type	Reference Image File	Reference Measurements		<= Primary Threshold	<= Secondary Threshold
			10:1	12:1	Pass	Nominal Pass
1	Flat	109-B109_R04_F13-B114_R03_F13_1000_02P	0.0086	0.0136	0.0098	0.0111
2	Flat	007-G007_R01_F11-B115_R08_F14_1000_09P	0.0066	0.0088	0.0072	0.0077
3	Flat	012-G012_R08_F14_1000_06P	0.0035	0.0063	0.0042	0.0049
4	Flat	005-G005_R08_F14_1000_07P	0.0062	0.0086	0.0068	0.0074
5	Flat	001-G001_R02_F13_1000_02P	0.0092	0.0144	0.0105	0.0118
6	Flat	253-U253_R09_F14_1000_10P	0.0088	0.0123	0.0097	0.0106
7	Flat	080-G080_R08_F14_1000_01P	0.0047	0.0059	0.0050	0.0053
8	Flat	146-B146_R06_F12_1000_03P	0.0063	0.0086	0.0069	0.0074
9	Flat	199-B199_R01_F11_1000_06P	0.0071	0.0096	0.0077	0.0083
10	Flat	106-B106_R08_F14_1000_05P	0.0085	0.0112	0.0092	0.0098
11	Rolled	086-G086_R09_F14_1000_09	0.0206	0.0289	0.0226	0.0247
12	Rolled	212-U212_R02_F13_1000_01	0.0255	0.0376	0.0286	0.0316
13	Rolled	004-G004_R08_F14-B121_R07_F14_1000_03	0.0204	0.0251	0.0216	0.0228
14	Rolled	007-G007_R01_F11-B115_R08_F14_1000_09	0.0164	0.0276	0.0192	0.0220
15	Rolled	112-B112_R02_F13_1000_10	0.0111	0.0268	0.0150	0.0189
16	Rolled	077-G077_R01_F11_1000_01	0.0161	0.0210	0.0173	0.0185
17	Rolled	033-G033_R07_F14_1000_06	0.0248	0.0344	0.0272	0.0296
18	Rolled	033-G033_R07_F14_1000_09	0.0240	0.0346	0.0266	0.0293
19	Rolled	146-B146_R06_F12_1000_03	0.0156	0.0249	0.0179	0.0202
20	Rolled	084-G084_R06_F12_1000_10	0.0137	0.0291	0.0176	0.0214
21	Slap	250-U250_R01_F11_1000_13	0.0016	0.0040	0.0022	0.0028
22	Slap	012-G012_R08_F14_1000_13	0.0044	0.0088	0.0055	0.0066
23	Slap	019-G019_R01_F11_1000_14	0.0108	0.0139	0.0116	0.0124
24	Slap	021-G021_R07_F14_1000_14	0.0067	0.0085	0.0071	0.0076
25	Slap	027-G027_R06_F12_1000_14	0.0075	0.0083	0.0077	0.0079
26	Slap	077-G077_R01_F11_1000_13	0.0076	0.0121	0.0087	0.0098
27	Slap	077-G077_R01_F11_1000_14	0.0070	0.0142	0.0088	0.0106
28	Slap	080-G080_R08_F14_1000_14	0.0040	0.0070	0.0048	0.0055
29	Slap	092-G092_R03_F13_1000_14	0.0067	0.0146	0.0087	0.0107
30	Slap	107-B107_R09_F14-B108_R06_F12_1000_14	0.0067	0.0082	0.0071	0.0075

6. Conformance Reports

Those suppliers who submit SP500-289 implementations of JPEG 2000 CODECs for conformance testing to NIST will receive back a conformance report that lists the outcome of applying the metrics in Section 5 to the pathway tests described in Section 4. In general there are 4 CODEC pathway tests (Table 4), which are conducted twice; the first time in 10:1 lossy compression mode, and the second time in lossless compression mode. Table 22 lists the metrics used to assess each pathway test. Note that decoder tests use the full suite of metrics for lossy compression, but only the first two metrics for lossless compression.

Table 22 – CODEC Pathway Test Details

		Lossy (10:1)	**Lossless**
ENCODER	**Test**	**Metrics**	**Metrics**
	1. E_S	M_{size}	M_{size}
		M_{struct}	M_{struct}
DECODER	**Tests**	**Metrics**	**Metrics**
	2. $E_S D_S$ 3. $E_S D_R$ 4. $E_R D_S$	M_{dim}	M_{dim}
		$M_{altered}$	$M_{altered}$
		M_{peak}	
		M_{MSD}	
		M_{SIVV}	

Table 23 shows a conformance report template. The table includes fields to record/report ratings for each metric applied; the summary rating for each test; as well as the Overall Rating. In general each metric rating may report: Gold Pass, Pass, Nominal Pass, or Fail (while not all metrics have the categories of Gold Pass and Nominal Pass). Test ratings are either Pass or Fail. For a conformance test to Pass, *all* its metrics must have a rating of Nominal Pass or better. The Overall Rating is also either Pass or Fail. For an Overall Result of Pass, each Test must have a rating of Pass.

Table 23 – Conformance Report Template

OVERALL RESULT = ____________			Lossy (10:1)		Lossless	
ENCODER	**Test**	**Grade**	**Metrics**	**Grades**	**Metrics**	**Grades**
	1. E_S		M_{size}		M_{size}	
			M_{struct}		M_{struct}	
DECODER	**Test**		**Metrics**		**Metrics**	
	2. E_SD_S		M_{dim}		M_{dim}	
			$M_{altered}$		$M_{altered}$	
			M_{peak}			
			M_{MSD}			
			M_{SIVV}			
DECODER	**Test**		**Metrics**		**Metrics**	
	3. E_SD_R		M_{dim}		M_{dim}	
			$M_{altered}$		$M_{altered}$	
			M_{peak}			
			M_{MSD}			
			M_{SIVV}			
DECODER	**Test**		**Metrics**		**Metrics**	
	4. E_RD_S		M_{dim}		M_{dim}	
			$M_{altered}$		$M_{altered}$	
			M_{peak}			
			M_{MSD}			
			M_{SIVV}			

7. Procedures for Conformance Testing

Those suppliers wishing to submit SP500-289 implementations of JPEG 2000 CODECs for conformance testing to NIST must follow the procedures outlined in this section. This includes obtaining a NIST assigned encoder identifier, downloading the NIST reference fingerprint image set (Section 7.1); running the NIST images through the supplier's CODEC and storing the resulting images (Section 0); submitting the supplier's CODEC images to NIST for evaluation (Section 7.4).

7.1. Obtaining a NIST Assigned Encoder Identifier

Prior to processing certification images, the supplier must obtain a NIST assigned encoder identifier. This identifier must be present in all images encoded by the supplier's CODEC, and must be present in conformance test images submitted to NIST for evaluation.

Requests for an encoder identifier must be sent to fingerprintcompression@nist.gov and the request must contain the following information in the subject and body of the message:

Message Subject should be:

JPEG2000 encoder identification request

In the message body please include:

Company point of contact name(s)
Company name
Company physical address

Company general phone number
Company point of contact phone number(s), if different than above

Company web site address

Email address to send assigned encoder identifier to.

Request urgency (either normal, or urgent)

CODEC target platform operating system (i.e., VendorX Linux)
Target platform operating system version and service-pack/build level
Target platform architecture (x86, x64, etc.)
Compiler used, including version and operating system at time of compilation

In 7 to 10 days typically, you will electronically receive the 100 byte NIST assigned encoder identifier.

This identifier must be present in all images processed by the supplier's CODEC.

Additionally, the electronic response you will receive from NIST will include a download link for the reference fingerprint image set needed by the supplier for testing.

7.2. Downloading NIST Reference Fingerprint Image Set

The supplier must download the NIST Reference Fingerprint Image Set from NIST. A link to download the NIST Reference Fingerprint Image Set will be provided by NIST in response to the request for NIST assigned vendor identifier (see 7.1).

The reference fingerprint data set will be archived within a portable ZIP format[8] container and organized as shown in Figure 3. The NIST-provided reference images are stored under the `NIST` subdirectory. Inside are the thirty source image files (P_{SRC}) stored in PGM format. The basenames of these files are what is listed in the fifth column of Table 2, which are appended with a tag and file extension, "`-SRC.pgm`". There are two additional processed files included with each source file. The first is the corresponding 10:1 lossy compressed file (J_{E_R}) processed using the NIST reference JPEG 2000 CODEC. This file is appended with tag and file extension, "`-ER.jp2`". The second processed file is the corresponding lossless compressed file using the reference CODEC appended with tag and file extension "`-LER.jp2`". In all there are 90 reference images included in the download package and listed in Table 24. Initially, the `Supplier` subdirectory is empty. The processed images generated by the supplier's CODEC will be stored in this folder and the entire package zipped back up and then submitted back to NIST for evaluation.

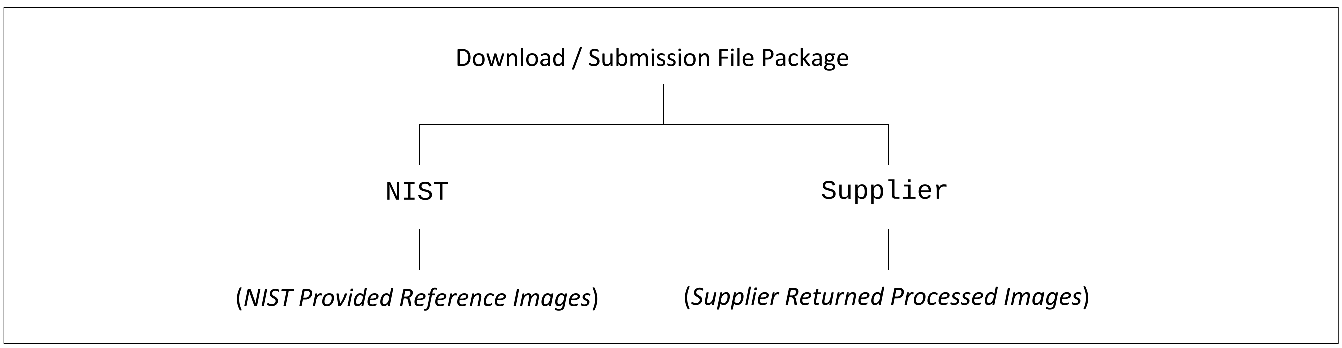

Figure 3 – Download / Submission File Package

[8] Per http://www.pkware.com/documents/casestudies/APPNOTE.TXT

Table 24 – NIST Reference Image Files

SOURCE FILE	10:1 PROCESSED FILE (E_R)	LOSSLESS PROCESSED FILE (E_R)
109-B109_R04_F13-B114_R03_F13_1000_02P-SRC.pgm	109-B109_R04_F13-B114_R03_F13_1000_02P-ER.jp2	109-B109_R04_F13-B114_R03_F13_1000_02P-LER.jp2
007-G007_R01_F11-B115_R08_F14_1000_09P-SRC.pgm	007-G007_R01_F11-B115_R08_F14_1000_09P-ER.jp2	007-G007_R01_F11-B115_R08_F14_1000_09P-LER.jp2
012-G012_R08_F14_1000_06P-SRC.pgm	012-G012_R08_F14_1000_06P-ER.jp2	012-G012_R08_F14_1000_06P-LER.jp2
005-G005_R08_F14_1000_07P-SRC.pgm	005-G005_R08_F14_1000_07P-ER.jp2	005-G005_R08_F14_1000_07P-LER.jp2
001-G001_R02_F13_1000_02P-SRC.pgm	001-G001_R02_F13_1000_02P-ER.jp2	001-G001_R02_F13_1000_02P-LER.jp2
253-U253_R09_F14_1000_10P-SRC.pgm	253-U253_R09_F14_1000_10P-ER.jp2	253-U253_R09_F14_1000_10P-LER.jp2
080-G080_R08_F14_1000_01P-SRC.pgm	080-G080_R08_F14_1000_01P-ER.jp2	080-G080_R08_F14_1000_01P-LER.jp2
146-B146_R06_F12_1000_03P-SRC.pgm	146-B146_R06_F12_1000_03P-ER.jp2	146-B146_R06_F12_1000_03P-LER.jp2
199-B199_R01_F11_1000_06P-SRC.pgm	199-B199_R01_F11_1000_06P-ER.jp2	199-B199_R01_F11_1000_06P-LER.jp2
106-B106_R08_F14_1000_05P-SRC.pgm	106-B106_R08_F14_1000_05P-ER.jp2	106-B106_R08_F14_1000_05P-LER.jp2
086-G086_R09_F14_1000_09-SRC.pgm	086-G086_R09_F14_1000_09-ER.jp2	086-G086_R09_F14_1000_09-LER.jp2
212-U212_R02_F13_1000_01-SRC.pgm	212-U212_R02_F13_1000_01-ER.jp2	212-U212_R02_F13_1000_01-LER.jp2
004-G004_R08_F14-B121_R07_F14_1000_03-SRC.pgm	004-G004_R08_F14-B121_R07_F14_1000_03-ER.jp2	004-G004_R08_F14-B121_R07_F14_1000_03-LER.jp2
007-G007_R01_F11-B115_R08_F14_1000_09-SRC.pgm	007-G007_R01_F11-B115_R08_F14_1000_09-ER.jp2	007-G007_R01_F11-B115_R08_F14_1000_09-LER.jp2
112-B112_R02_F13_1000_10-SRC.pgm	112-B112_R02_F13_1000_10-ER.jp2	112-B112_R02_F13_1000_10-LER.jp2
077-G077_R01_F11_1000_01-SRC.pgm	077-G077_R01_F11_1000_01-ER.jp2	077-G077_R01_F11_1000_01-LER.jp2
033-G033_R07_F14_1000_06-SRC.pgm	033-G033_R07_F14_1000_06-ER.jp2	033-G033_R07_F14_1000_06-LER.jp2
033-G033_R07_F14_1000_09-SRC.pgm	033-G033_R07_F14_1000_09-ER.jp2	033-G033_R07_F14_1000_09-LER.jp2
146-B146_R06_F12_1000_03-SRC.pgm	146-B146_R06_F12_1000_03-ER.jp2	146-B146_R06_F12_1000_03-LER.jp2
084-G084_R06_F12_1000_10-SRC.pgm	084-G084_R06_F12_1000_10-ER.jp2	084-G084_R06_F12_1000_10-LER.jp2
250-U250_R01_F11_1000_13-SRC.pgm	250-U250_R01_F11_1000_13-ER.jp2	250-U250_R01_F11_1000_13-LER.jp2
012-G012_R08_F14_1000_13-SRC.pgm	012-G012_R08_F14_1000_13-ER.jp2	012-G012_R08_F14_1000_13-LER.jp2
019-G019_R01_F11_1000_14-SRC.pgm	019-G019_R01_F11_1000_14-ER.jp2	019-G019_R01_F11_1000_14-LER.jp2
021-G021_R07_F14_1000_14-SRC.pgm	021-G021_R07_F14_1000_14-ER.jp2	021-G021_R07_F14_1000_14-LER.jp2
027-G027_R06_F12_1000_14-SRC.pgm	027-G027_R06_F12_1000_14-ER.jp2	027-G027_R06_F12_1000_14-LER.jp2
077-G077_R01_F11_1000_13-SRC.pgm	077-G077_R01_F11_1000_13-ER.jp2	077-G077_R01_F11_1000_13-LER.jp2
077-G077_R01_F11_1000_14-SRC.pgm	077-G077_R01_F11_1000_14-ER.jp2	077-G077_R01_F11_1000_14-LER.jp2
080-G080_R08_F14_1000_14-SRC.pgm	080-G080_R08_F14_1000_14-ER.jp2	080-G080_R08_F14_1000_14-LER.jp2
092-G092_R03_F13_1000_14-SRC.pgm	092-G092_R03_F13_1000_14-ER.jp2	092-G092_R03_F13_1000_14-LER.jp2
107-B107_R09_F14-B108_R06_F12_1000_14-SRC.pgm	107-B107_R09_F14-B108_R06_F12_1000_14-ER.jp2	107-B107_R09_F14-B108_R06_F12_1000_14-LER.jp2

7.3. Running the Testing Protocol

Upon downloading and unpacking the reference image set, the supplier then executes the testing protocol by running the images systematically through their implementation of the JPEG 2000 CODEC.

7.3.1. Preparing Files for Encoder Test 1 (E_S)

Referencing the tests in the order listed in the conformance report template (Table 23), the supplier prepares results for the Encoder Test 1 (E_S) by taking each of the source reference files and compressing it using their JPEG 2000 encoder, on one pass using 10:1 lossy compression, and another using lossless compression. The 10:1 lossy compressed image is stored using the source file's basename appended with the tag and extension, "`-ES.jp2`", while the lossless compressed image is stored using the same basename appended with the tag and extension, "`-LES.jp2`". Table 25 lists the processed files that are to be generated by this stage and stored under the `Supplier` subdirectory.

Table 25 – Supplier Prepared Files for Encoder Test 1 (E_S)

10:1 PROCESSED FILE (E_S)	LOSSLESS PROCESSED FILE (E_S)
109-B109_R04_F13-B114_R03_F13_1000_02P-ES.jp2	109-B109_R04_F13-B114_R03_F13_1000_02P-LES.jp2
007-G007_R01_F11-B115_R08_F14_1000_09P-ES.jp2	007-G007_R01_F11-B115_R08_F14_1000_09P-LES.jp2
012-G012_R08_F14_1000_06P-ES.jp2	012-G012_R08_F14_1000_06P-LES.jp2
005-G005_R08_F14_1000_07P-ES.jp2	005-G005_R08_F14_1000_07P-LES.jp2
001-G001_R02_F13_1000_02P-ES.jp2	001-G001_R02_F13_1000_02P-LES.jp2
253-U253_R09_F14_1000_10P-ES.jp2	253-U253_R09_F14_1000_10P-LES.jp2
080-G080_R08_F14_1000_01P-ES.jp2	080-G080_R08_F14_1000_01P-LES.jp2
146-B146_R06_F12_1000_03P-ES.jp2	146-B146_R06_F12_1000_03P-LES.jp2
199-B199_R01_F11_1000_06P-ES.jp2	199-B199_R01_F11_1000_06P-LES.jp2
106-B106_R08_F14_1000_05P-ES.jp2	106-B106_R08_F14_1000_05P-LES.jp2
086-G086_R09_F14_1000_09-ES.jp2	086-G086_R09_F14_1000_09-LES.jp2
212-U212_R02_F13_1000_01-ES.jp2	212-U212_R02_F13_1000_01-LES.jp2
004-G004_R08_F14-B121_R07_F14_1000_03-ES.jp2	004-G004_R08_F14-B121_R07_F14_1000_03-LES.jp2
007-G007_R01_F11-B115_R08_F14_1000_09-ES.jp2	007-G007_R01_F11-B115_R08_F14_1000_09-LES.jp2
112-B112_R02_F13_1000_10-ES.jp2	112-B112_R02_F13_1000_10-LES.jp2
077-G077_R01_F11_1000_01-ES.jp2	077-G077_R01_F11_1000_01-LES.jp2
033-G033_R07_F14_1000_06-ES.jp2	033-G033_R07_F14_1000_06-LES.jp2
033-G033_R07_F14_1000_09-ES.jp2	033-G033_R07_F14_1000_09-LES.jp2
146-B146_R06_F12_1000_03-ES.jp2	146-B146_R06_F12_1000_03-LES.jp2
084-G084_R06_F12_1000_10-ES.jp2	084-G084_R06_F12_1000_10-LES.jp2
250-U250_R01_F11_1000_13-ES.jp2	250-U250_R01_F11_1000_13-LES.jp2
012-G012_R08_F14_1000_13-ES.jp2	012-G012_R08_F14_1000_13-LES.jp2
019-G019_R01_F11_1000_14-ES.jp2	019-G019_R01_F11_1000_14-LES.jp2
021-G021_R07_F14_1000_14-ES.jp2	021-G021_R07_F14_1000_14-LES.jp2
027-G027_R06_F12_1000_14-ES.jp2	027-G027_R06_F12_1000_14-LES.jp2
077-G077_R01_F11_1000_13-ES.jp2	077-G077_R01_F11_1000_13-LES.jp2
077-G077_R01_F11_1000_14-ES.jp2	077-G077_R01_F11_1000_14-LES.jp2
080-G080_R08_F14_1000_14-ES.jp2	080-G080_R08_F14_1000_14-LES.jp2
092-G092_R03_F13_1000_14-ES.jp2	092-G092_R03_F13_1000_14-LES.jp2
107-B107_R09_F14-B108_R06_F12_1000_14-ES.jp2	107-B107_R09_F14-B108_R06_F12_1000_14-LES.jp2

7.3.2. Preparing Files for Decoder Test 2 (E_SD_S)

The supplier prepares results for the Decoder Test 2 (E_SD_S) by taking each of the compressed files from Encoder Test 1 (Table 25) and running them through the supplier's JPEG 2000 decoder. Both the 10:1 lossy compressed and lossless compressed image are decoded and stored as PGM processed files. The decoded 10:1 lossy compressed image is stored using the tag and extension, "`-ESDS.pgm`", and the decoded lossless compressed image is stored using the tag and extension, "`-LESDS.pgm`". Table 26 lists the processed files that are to be generated by this stage and stored under the `Supplier` subdirectory.

Table 26 – Supplier Prepared Files for Decoder Test 2 (E_SD_S)

10:1 PROCESSED FILE (E_SD_S)	LOSSLESS PROCESSED FILE (E_SD_S)
109-B109_R04_F13-B114_R03_F13_1000_02P-ESDS.pgm	109-B109_R04_F13-B114_R03_F13_1000_02P-LESDS.pgm
007-G007_R01_F11-B115_R08_F14_1000_09P-ESDS.pgm	007-G007_R01_F11-B115_R08_F14_1000_09P-LESDS.pgm
012-G012_R08_F14_1000_06P-ESDS.pgm	012-G012_R08_F14_1000_06P-LESDS.pgm
005-G005_R08_F14_1000_07P-ESDS.pgm	005-G005_R08_F14_1000_07P-LESDS.pgm
001-G001_R02_F13_1000_02P-ESDS.pgm	001-G001_R02_F13_1000_02P-LESDS.pgm
253-U253_R09_F14_1000_10P-ESDS.pgm	253-U253_R09_F14_1000_10P-LESDS.pgm
080-G080_R08_F14_1000_01P-ESDS.pgm	080-G080_R08_F14_1000_01P-LESDS.pgm
146-B146_R06_F12_1000_03P-ESDS.pgm	146-B146_R06_F12_1000_03P-LESDS.pgm
199-B199_R01_F11_1000_06P-ESDS.pgm	199-B199_R01_F11_1000_06P-LESDS.pgm
106-B106_R08_F14_1000_05P-ESDS.pgm	106-B106_R08_F14_1000_05P-LESDS.pgm
086-G086_R09_F14_1000_09-ESDS.pgm	086-G086_R09_F14_1000_09-LESDS.pgm
212-U212_R02_F13_1000_01-ESDS.pgm	212-U212_R02_F13_1000_01-LESDS.pgm
004-G004_R08_F14-B121_R07_F14_1000_03-ESDS.pgm	004-G004_R08_F14-B121_R07_F14_1000_03-LESDS.pgm
007-G007_R01_F11-B115_R08_F14_1000_09-ESDS.pgm	007-G007_R01_F11-B115_R08_F14_1000_09-LESDS.pgm
112-B112_R02_F13_1000_10-ESDS.pgm	112-B112_R02_F13_1000_10-LESDS.pgm
077-G077_R01_F11_1000_01-ESDS.pgm	077-G077_R01_F11_1000_01-LESDS.pgm
033-G033_R07_F14_1000_06-ESDS.pgm	033-G033_R07_F14_1000_06-LESDS.pgm
033-G033_R07_F14_1000_09-ESDS.pgm	033-G033_R07_F14_1000_09-LESDS.pgm
146-B146_R06_F12_1000_03-ESDS.pgm	146-B146_R06_F12_1000_03-LESDS.pgm
084-G084_R06_F12_1000_10-ESDS.pgm	084-G084_R06_F12_1000_10-LESDS.pgm
250-U250_R01_F11_1000_13-ESDS.pgm	250-U250_R01_F11_1000_13-LESDS.pgm
012-G012_R08_F14_1000_13-ESDS.pgm	012-G012_R08_F14_1000_13-LESDS.pgm
019-G019_R01_F11_1000_14-ESDS.pgm	019-G019_R01_F11_1000_14-LESDS.pgm
021-G021_R07_F14_1000_14-ESDS.pgm	021-G021_R07_F14_1000_14-LESDS.pgm
027-G027_R06_F12_1000_14-ESDS.pgm	027-G027_R06_F12_1000_14-LESDS.pgm
077-G077_R01_F11_1000_13-ESDS.pgm	077-G077_R01_F11_1000_13-LESDS.pgm
077-G077_R01_F11_1000_14-ESDS.pgm	077-G077_R01_F11_1000_14-LESDS.pgm
080-G080_R08_F14_1000_14-ESDS.pgm	080-G080_R08_F14_1000_14-LESDS.pgm
092-G092_R03_F13_1000_14-ESDS.pgm	092-G092_R03_F13_1000_14-LESDS.pgm
107-B107_R09_F14-B108_R06_F12_1000_14-ESDS.pgm	107-B107_R09_F14-B108_R06_F12_1000_14-LESDS.pgm

7.3.3. Preparing Files for Decoder Test 3 (E_SD_R)

Decoder Test 3 (E_SD_R) will be completed by NIST, using the reference decoder to process each of the files compressed using the Supplier's encoder. As with Decoder Test 2, both the 10:1 lossy compressed and lossless compressed images resulting from Encoder Test 1 will be decoded and evaluated. As the supplier will have already included the files listed in Table 25 under the `Supplier` subdirectory, no further action is required by the supplier in order to prepare for Decoder Test 3 (E_SD_R).

7.3.4. Preparing Files for Decoder Test 4 (E_RD_S)

The supplier prepares results for the decoder test 4 (E_RD_S) by taking each of the compressed files generated by the NIST reference encoder and provided within the reference image set (Table 24, columns 2 and 3) and running them through the supplier's decoder. Both the 10:1 lossy compressed and lossless compressed image are decoded and stored as PGM processed files. The decoded 10:1 lossy compressed image is stored using the tag and extension, "`-ERDS.pgm`", and the decoded lossless compressed image is stored using the tag and extension, "`-LERDS.pgm`". Table 27 lists the processed files that are to be generated by this stage and stored under the `Supplier` subdirectory.

Table 27 – Supplier Prepared Files for Decoder Test 4 (E_RD_S)

10:1 PROCESSED FILE (E_RD_S)	LOSSLESS PROCESSED FILE (E_RD_S)
109-B109_R04_F13-B114_R03_F13_1000_02P-ERDS.pgm	109-B109_R04_F13-B114_R03_F13_1000_02P-LERDS.pgm
007-G007_R01_F11-B115_R08_F14_1000_09P-ERDS.pgm	007-G007_R01_F11-B115_R08_F14_1000_09P-LERDS.pgm
012-G012_R08_F14_1000_06P-ERDS.pgm	012-G012_R08_F14_1000_06P-LERDS.pgm
005-G005_R08_F14_1000_07P-ERDS.pgm	005-G005_R08_F14_1000_07P-LERDS.pgm
001-G001_R02_F13_1000_02P-ERDS.pgm	001-G001_R02_F13_1000_02P-LERDS.pgm
253-U253_R09_F14_1000_10P-ERDS.pgm	253-U253_R09_F14_1000_10P-LERDS.pgm
080-G080_R08_F14_1000_01P-ERDS.pgm	080-G080_R08_F14_1000_01P-LERDS.pgm
146-B146_R06_F12_1000_03P-ERDS.pgm	146-B146_R06_F12_1000_03P-LERDS.pgm
199-B199_R01_F11_1000_06P-ERDS.pgm	199-B199_R01_F11_1000_06P-LERDS.pgm
106-B106_R08_F14_1000_05P-ERDS.pgm	106-B106_R08_F14_1000_05P-LERDS.pgm
086-G086_R09_F14_1000_09-ERDS.pgm	086-G086_R09_F14_1000_09-LERDS.pgm
212-U212_R02_F13_1000_01-ERDS.pgm	212-U212_R02_F13_1000_01-LERDS.pgm
004-G004_R08_F14-B121_R07_F14_1000_03-ERDS.pgm	004-G004_R08_F14-B121_R07_F14_1000_03-LERDS.pgm
007-G007_R01_F11-B115_R08_F14_1000_09-ERDS.pgm	007-G007_R01_F11-B115_R08_F14_1000_09-LERDS.pgm
112-B112_R02_F13_1000_10-ERDS.pgm	112-B112_R02_F13_1000_10-LERDS.pgm
077-G077_R01_F11_1000_01-ERDS.pgm	077-G077_R01_F11_1000_01-LERDS.pgm
033-G033_R07_F14_1000_06-ERDS.pgm	033-G033_R07_F14_1000_06-LERDS.pgm
033-G033_R07_F14_1000_09-ERDS.pgm	033-G033_R07_F14_1000_09-LERDS.pgm
146-B146_R06_F12_1000_03-ERDS.pgm	146-B146_R06_F12_1000_03-LERDS.pgm
084-G084_R06_F12_1000_10-ERDS.pgm	084-G084_R06_F12_1000_10-LERDS.pgm
250-U250_R01_F11_1000_13-ERDS.pgm	250-U250_R01_F11_1000_13-LERDS.pgm
012-G012_R08_F14_1000_13-ERDS.pgm	012-G012_R08_F14_1000_13-LERDS.pgm
019-G019_R01_F11_1000_14-ERDS.pgm	019-G019_R01_F11_1000_14-LERDS.pgm
021-G021_R07_F14_1000_14-ERDS.pgm	021-G021_R07_F14_1000_14-LERDS.pgm
027-G027_R06_F12_1000_14-ERDS.pgm	027-G027_R06_F12_1000_14-LERDS.pgm
077-G077_R01_F11_1000_13-ERDS.pgm	077-G077_R01_F11_1000_13-LERDS.pgm
077-G077_R01_F11_1000_14-ERDS.pgm	077-G077_R01_F11_1000_14-LERDS.pgm
080-G080_R08_F14_1000_14-ERDS.pgm	080-G080_R08_F14_1000_14-LERDS.pgm
092-G092_R03_F13_1000_14-ERDS.pgm	092-G092_R03_F13_1000_14-LERDS.pgm
107-B107_R09_F14-B108_R06_F12_1000_14-ERDS.pgm	107-B107_R09_F14-B108_R06_F12_1000_14-LERDS.pgm

7.4. Submitting Processed Images to NIST for Evaluation

Upon supplier's successful completion of the testing protocol, the `Supplier` subdirectory of the prepared file submission package (Figure 3) must contain all 180 processed files listed in Table 25 through Table 27. The submission package (including the `NIST` subdirectory) must be zipped and submitted to NIST either electronically or by parcel delivery. The submission package must not contain any executable code, or macro enabled content. The submission package must not contain any proprietary or sensitive information.

7.4.1. Submitting Electronically

The supplier's zipped file package may be submitted to NIST by contacting the official JPEG2000 CODEC Test Custodian fingerprintcompression@nist.gov in order to request an account for the NIST Secure File Transfer Service (or receive alternative instructions). The email's subject line must be: "JPEG2000 encoder conformance submittal"

See http://www.nist.gov/itl/iad/ig/compression.cfm for the most up-to-date information on the submission of processed image packages for evaluation.

7.4.2. Submitting Parcel Post

The supplier's zipped file package may be submitted to NIST on a data-DVD (DVD-R or DVD+R), and mailed back to NIST using the following address:

JPEG2000 CODEC Test Custodian
ITL-IAD-Image Group
100 Bureau Drive MS 8940
Gaithersburg, MD 20899-8940

The supplier's zipped file must not contain any binary executable code, and must not include any information deemed proprietary by the supplier. All data submitted to NIST for testing will become the property of NIST.

7.4.3. FBI Certification

If the testing protocol is complete and the supplier's results satisfactorily meet the requirements set forth in this document, then NIST notifies the FBI CJIS Division that the supplier received an Overall Result of Pass. Subsequently, the FBI CJIS Division issues a letter certifying that the supplier's implementation of a JPEG 2000 CODEC is conformant with the specification set forth in SP 500-289. An implementation ID and a description of the supplier's submission will then be added to the current list of approved implementations maintained by the FBI.

This implementation ID will remain hard coded into the supplier solution and included in all JPEG2000 encoded output from the supplier CODEC according to this specification (see section 5.1.3 and section 4.3 of [NIST3] for additional details).

Note: The FBI certification for an implementation will apply only to a specific configuration. A configuration encompasses the software version of the encoder/decoder, hardware platform, operating system, and compiler used. If any of these components change resulting in a binary level change in any of the files the supplier sent to NIST for the purposes of the initial certification, then a recertification including a new implementation ID will be required.

Also note that the certification process is not intended to endorse one implementation over another, but merely to certify that the implementation meets FBI standards. The FBI does not recommend one certified implementation over another.

8. References

8.1. Publications and Reports

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Appendix A. **PGM Profile**

Portable Graymap Format (PGM) is one of several image formats defined by Netpbm [PGM], an open-source programming library. PGM is a widely-supported and very straight-forward image format consisting of a small, simplified header followed by uncompressed 8- or 16-bit raw image data in ASCII or binary encodings.

A valid PGM file header always begins with a two-byte string which indicates that the file is a PGM image containing grayscale image data encoded in either ASCII (“P2”) or binary (“P5”). Binary-encoded files are generally smaller in size and are preferred in most cases, including the storage of fingerprint images. The two-byte format identification string is followed by decimal values defining the width, height, and maximum gray value; each separated by whitespace characters such as spaces, tabs, carriage-returns (CRs) or line-feeds (LFs). The header is always encoded as ASCII and is terminated by a whitespace character, which also marks the beginning of the image data (which may be either ASCII- or binary-encoded). The header may also contain comments as strings beginning with the ‘#’ character and terminated by a CR or LF character.

Table 28 – PGM File Structure and Metadata

PGM Data Field	Value	Size (Bytes)	Hexadecimal
PGM Signature	‘P5 ’	3	50 35 0A
Comment	Comment String	variable	
Width	Image Width (pixels)	variable	
Height	Image Height (pixels)	variable	
Max Value	’255 ‘	4	32 35 35 0A