NIST Special Publication 500-300

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.
08/2020	Several updates made to reflect a change in the Reference Fingerprint Image Set, described in section 3.1, including updates to Table 2, Table 7, Table 8, Table 14, Table 17, Table 19, Table 21, and Table 22 - Table 25. An update clarifying the application of the Peak Pixel Difference metric was also made in section 5.2.3.

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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 [NIST3]. 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

[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 [NIST3], 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 CODECs to ensure they meet the operational characteristics resulting from the application of parameters defined in NIST

[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.

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 [NIST3]. 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 300 (SD-300) [NIST6] based on their sensitivity to compression changes as measured by spectral frequency comparison of compressed images with non-compressed original fingerprint impressions acquired at 1000 ppi [LIBERT] and confirmed by human assessors.

In [NIST2] we report that trained fingerprint examiners observed in most cases the increased degradation in image quality over the three compression rations, 7:1, 10:1, and 12:1. The analysis of examiner ratings found 10:1 compression the threshold beyond which image degradation became sufficiently significant as to possibly impact latent matching. In selecting images from SD-300, we did not have benefit of large numbers of trained examiners. However, we were able to extend the examiner results to the new dataset by looking for the maximum distortion of image spectra in comparison to non-compressed exemplars with versions our source images compressed at 7:1 and 12:1. The procedure can be summarized as follows:

1. Select a subset of 600 source images at random from SD-300;
2. Apply the JPEG 2000 encoder to each source image at rates 7:1, 10:1, and 12:1;
3. Apply the NIST Spectral Image Verification Validation (SIVV) metric [LIBERT] to extract power spectrum for each of the compressed images as well as that of the non-compressed source;
4. Compute the Root Mean Squared Difference (RMSD) between the power spectra of each of the compressed images and that of its source;
5. For each of the 600 RMSD values, compute the slope of the line fitting the RMSD values at 7:1, 10:1, and 12:1 and sort the values from highest to lowest slope;
6. Select the 200 source images exhibiting the greatest slope in RMSD from 7:1 to 12:1.
7. To confirm that degradation would be visible to observers, the 7:1, 10:1, and 12:1 compressed versions of each of the selected 200 source images were presented, in a randomized order of “triplets”, to a group of experienced human assessors using customized software for collecting their assessments
8. The group of assessors ranked each image within a triplet from the highest to lowest quality until the entire set of 200 was completed (for each assessor)
9. A subset of 30 source images was selected for which agreement among all assessors was reached

Images selected by the computational method and verified by human inspection are listed in Table 2 below.

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
1	Flat	540	860	S0011_1000_08P-SRC
2	Flat	630	930	S0187_1000_07P-SRC
3	Flat	662	890	S0201_1000_02P-SRC
4	Flat	720	1850	S0417_1000_11-SRC
5	Flat	470	870	S0464_1000_09P-SRC
6	Flat	600	900	S0564_1000_03P-SRC
7	Flat	560	950	S0586_1000_10P-SRC
8	Flat	748	1782	S0676_1000_12-SRC
9	Flat	580	580	S0704_1000_05P-SRC
10	Flat	590	930	S0730_1000_04P-SRC
11	Rolled	1550	1496	S0051_1000_05-SRC
12	Rolled	1536	1592	S0093_1000_01-SRC
13	Rolled	1618	1606	S0152_1000_06-SRC
14	Rolled	1496	1498	S0176_1000_02-SRC
15	Rolled	1536	1334	S0249_1000_08-SRC
16	Rolled	1524	1484	S0342_1000_09-SRC
17	Rolled	1522	1402	S0397_1000_04-SRC
18	Rolled	1470	1414	S0503_1000_07-SRC
19	Rolled	1482	1414	S0705_1000_03-SRC
20	Rolled	1592	1400	S0724_1000_10-SRC
21	Slap	3196	1890	S0139_1000_13-SRC
22	Slap	3208	1986	S0286_1000_13-SRC
23	Slap	3168	1958	S0304_1000_14-SRC
24	Slap	3102	2014	S0392_1000_13-SRC
25	Slap	3100	2000	S0465_1000_14-SRC
26	Slap	3208	1986	S0466_1000_13-SRC
27	Slap	3156	1890	S0641_1000_14-SRC
28	Slap	3086	1850	S0795_1000_14-SRC
29	Slap	3208	1986	S0817_1000_13-SRC
30	Slap	3182	1836	S0850_1000_14-SRC

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. 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_RD_R	**E_SD_S**	**E_RD_S**	**E_SD_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, '$P_{E_SD_R}$'. 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.

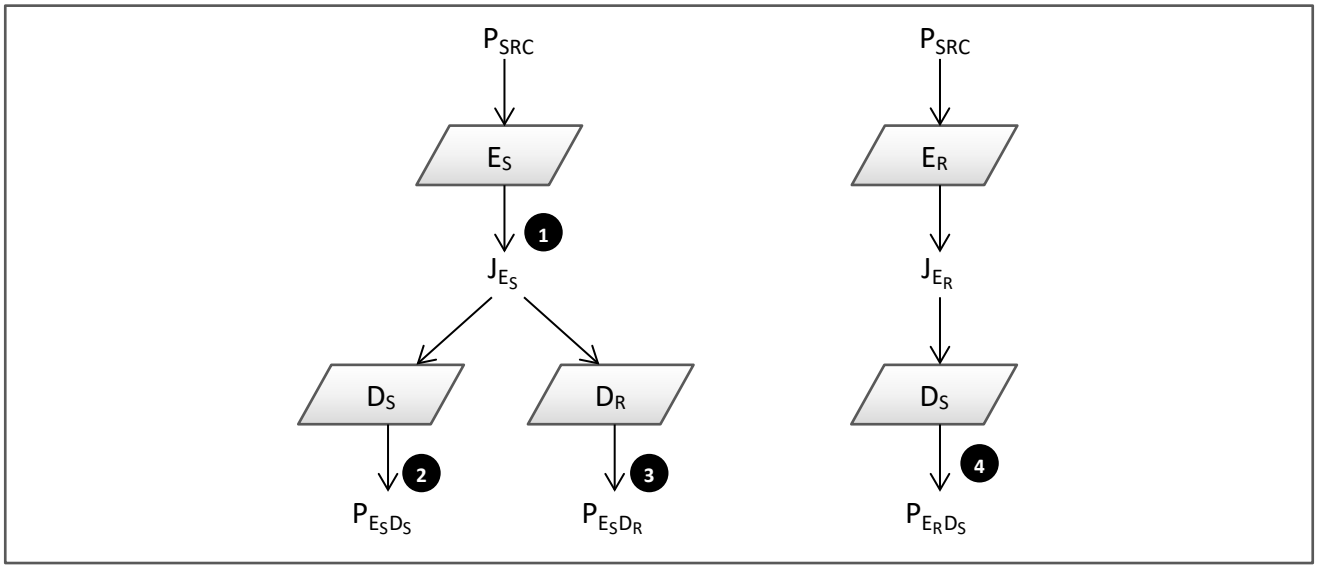

Figure 1 – CODEC Pathways and Input / Output Images

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_SD_S	$P_{E_SD_S}$, P_{SRC}
3	E_SD_R	$P_{E_SD_R}$, P_{SRC}
4	E_RD_S	$P_{E_RD_S}$, 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[4] 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.

[4] 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.[5]

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

[5] 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	S0011_1000_08P-ER.jp2	46 436	48 758	51 080
2	Flat	S0187_1000_07P-ER.jp2	58 587	61 517	64 446
3	Flat	S0201_1000_02P-ER.jp2	58 816	61 757	64 698
4	Flat	S0417_1000_11-ER.jp2	133 040	139 692	146 344
5	Flat	S0464_1000_09P-ER.jp2	40 832	42 874	44 916
6	Flat	S0564_1000_03P-ER.jp2	53 982	56 682	59 381
7	Flat	S0586_1000_10P-ER.jp2	53 133	55 790	58 447
8	Flat	S0676_1000_12-ER.jp2	133 270	139 934	146 597
9	Flat	S0704_1000_05P-ER.jp2	33 586	35 266	36 945
10	Flat	S0730_1000_04P-ER.jp2	54 870	57 614	60 357
11	Rolled	S0051_1000_05-ER.jp2	231 870	243 464	255 057
12	Rolled	S0093_1000_01-ER.jp2	244 423	256 645	268 866
13	Rolled	S0152_1000_06-ER.jp2	259 630	272 612	285 593
14	Rolled	S0176_1000_02-ER.jp2	223 879	235 073	246 267
15	Rolled	S0249_1000_08-ER.jp2	204 796	215 036	225 276
16	Rolled	S0342_1000_09-ER.jp2	226 139	237 446	248 753
17	Rolled	S0397_1000_04-ER.jp2	213 167	223 826	234 484
18	Rolled	S0503_1000_07-ER.jp2	207 617	217 998	228 379
19	Rolled	S0705_1000_03-ER.jp2	209 527	220 004	230 480
20	Rolled	S0724_1000_10-ER.jp2	222 856	233 999	245 142
21	Slap	S0139_1000_13-ER.jp2	603 779	633 968	664 157
22	Slap	S0286_1000_13-ER.jp2	637 109	668 965	700 820
23	Slap	S0304_1000_14-ER.jp2	620 026	651 028	682 029
24	Slap	S0392_1000_13-ER.jp2	624 604	655 835	687 065
25	Slap	S0465_1000_14-ER.jp2	619 989	650 989	681 988
26	Slap	S0466_1000_13-ER.jp2	637 003	668 854	700 704
27	Slap	S0641_1000_14-ER.jp2	596 373	626 192	656 011
28	Slap	S0795_1000_14-ER.jp2	570 751	599 289	627 827
29	Slap	S0817_1000_13-ER.jp2	637 108	668 964	700 819
30	Slap	S0850_1000_14-ER.jp2	584 161	613 370	642 578

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	S0011_1000_08P-LER.jp2	232 773	244 412	256 051
2	Flat	S0187_1000_07P-LER.jp2	277 215	291 076	304 937
3	Flat	S0201_1000_02P-LER.jp2	271 663	285 247	298 830
4	Flat	S0417_1000_11-LER.jp2	626 452	657 775	689 098
5	Flat	S0464_1000_09P-LER.jp2	198 169	208 078	217 986
6	Flat	S0564_1000_03P-LER.jp2	277 351	291 219	305 087
7	Flat	S0586_1000_10P-LER.jp2	273 112	286 768	300 424
8	Flat	S0676_1000_12-LER.jp2	517 174	543 033	568 892
9	Flat	S0704_1000_05P-LER.jp2	168 205	176 616	185 026
10	Flat	S0730_1000_04P-LER.jp2	268 649	282 082	295 514
11	Rolled	S0051_1000_05-LER.jp2	1 064 588	1 117 818	1 171 047
12	Rolled	S0093_1000_01-LER.jp2	1 138 901	1 195 847	1 252 792
13	Rolled	S0152_1000_06-LER.jp2	1 234 459	1 296 182	1 357 905
14	Rolled	S0176_1000_02-LER.jp2	1 098 514	1 153 440	1 208 366
15	Rolled	S0249_1000_08-LER.jp2	1 003 864	1 054 058	1 104 251
16	Rolled	S0342_1000_09-LER.jp2	1 085 240	1 139 502	1 193 764
17	Rolled	S0397_1000_04-LER.jp2	1 019 982	1 070 982	1 121 981
18	Rolled	S0503_1000_07-LER.jp2	978 388	1 027 308	1 076 227
19	Rolled	S0705_1000_03-LER.jp2	953 767	1 001 456	1 049 144
20	Rolled	S0724_1000_10-LER.jp2	1 028 500	1 079 925	1 131 350
21	Slap	S0139_1000_13-LER.jp2	2 639 358	2 771 326	2 903 294
22	Slap	S0286_1000_13-LER.jp2	3 196 022	3 355 824	3 515 625
23	Slap	S0304_1000_14-LER.jp2	2 483 632	2 607 814	2 731 996
24	Slap	S0392_1000_13-LER.jp2	2 673 289	2 806 954	2 940 618
25	Slap	S0465_1000_14-LER.jp2	2 761 384	2 899 454	3 037 523
26	Slap	S0466_1000_13-LER.jp2	2 756 295	2 894 110	3 031 925
27	Slap	S0641_1000_14-LER.jp2	2 467 987	2 591 387	2 714 786
28	Slap	S0795_1000_14-LER.jp2	2 460 837	2 583 879	2 706 921
29	Slap	S0817_1000_13-LER.jp2	2 897 104	3 041 960	3 186 815
30	Slap	S0850_1000_14-LER.jp2	2 400 488	2 520 513	2 640 537

5.1.2. Compressed File Structure and Metadata

Table 9 – 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[6]	2	99CA
Vertical Capture Resolution Denominator (VRcD)	1	2	0001
Horizontal Capture Resolution Numerator (HRcN)	39 370[6]	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	

[6] 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.

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

Table 10 – Compressed File Structure and Metadata – Grades

Pass	$M_{struct}(J_{E_S})$, Criteria in Table 9 strictly met
Fail	$M_{struct}(J_{E_S})$, Criteria in Table 9 is not strictly met

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 6 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., $P_{E_SD_R}$). 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., $M_{dim}(P_{E_SD_R}, P_{SRC})$
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

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

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

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

We then count the total number of changed pixels as

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

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	S0011_1000_08P-SRC.pgm	391 852	397 494	393 263	394 673
2	Flat	S0187_1000_07P-SRC.pgm	478 065	490 211	481 102	484 138
3	Flat	S0201_1000_02P-SRC.pgm	469 514	481 034	472 394	475 274
4	Flat	S0417_1000_11-SRC.pgm	1 092 182	1 118 798	1 098 836	1 105 490
5	Flat	S0464_1000_09P-SRC.pgm	338 666	346 175	340 543	342 421
6	Flat	S0564_1000_03P-SRC.pgm	461 621	468 273	463 284	464 947
7	Flat	S0586_1000_10P-SRC.pgm	455 618	460 669	456 881	458 144
8	Flat	S0676_1000_12-SRC.pgm	943 253	979 479	952 310	961 366
9	Flat	S0704_1000_05P-SRC.pgm	287 277	290 954	288 196	289 116
10	Flat	S0730_1000_04P-SRC.pgm	459 019	467 160	461 054	463 090
11	Rolled	S0051_1000_05-SRC.pgm	1 860 517	1 911 125	1 873 169	1 885 821
12	Rolled	S0093_1000_01-SRC.pgm	1 983 255	2 036 445	1 996 553	2 009 850
13	Rolled	S0152_1000_06-SRC.pgm	2 142 413	2 192 629	2 154 967	2 167 521
14	Rolled	S0176_1000_02-SRC.pgm	1 875 992	1 914 548	1 885 631	1 895 270
15	Rolled	S0249_1000_08-SRC.pgm	1 708 272	1 741 492	1 716 577	1 724 882
16	Rolled	S0342_1000_09-SRC.pgm	1 878 842	1 917 308	1 888 459	1 898 075
17	Rolled	S0397_1000_04-SRC.pgm	1 755 274	1 800 625	1 766 612	1 777 950
18	Rolled	S0503_1000_07-SRC.pgm	1 699 051	1 744 889	1 710 511	1 721 970
19	Rolled	S0705_1000_03-SRC.pgm	1 679 192	1 730 520	1 692 024	1 704 856
20	Rolled	S0724_1000_10-SRC.pgm	1 803 623	1 853 564	1 816 108	1 828 594
21	Slap	S0139_1000_13-SRC.pgm	4 667 198	4 823 830	4 706 356	4 745 514
22	Slap	S0286_1000_13-SRC.pgm	5 412 337	5 495 599	5 433 153	5 453 968
23	Slap	S0304_1000_14-SRC.pgm	4 418 345	4 558 482	4 453 379	4 488 414
24	Slap	S0392_1000_13-SRC.pgm	4 685 112	4 856 213	4 727 887	4 770 663
25	Slap	S0465_1000_14-SRC.pgm	4 870 952	5 010 692	4 905 887	4 940 822
26	Slap	S0466_1000_13-SRC.pgm	4 852 427	5 026 205	4 895 872	4 939 316
27	Slap	S0641_1000_14-SRC.pgm	4 426 848	4 566 900	4 461 861	4 496 874
28	Slap	S0795_1000_14-SRC.pgm	4 393 716	4 526 321	4 426 867	4 460 019
29	Slap	S0817_1000_13-SRC.pgm	5 095 847	5 244 884	5 133 106	5 170 366
30	Slap	S0850_1000_14-SRC.pgm	4 343 816	4 482 193	4 378 410	4 413 005

5.2.2.2. Altered Pixel Count (for Lossless Compression)

The criteria for evaluating lossless compression in regard 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., $P_{E_SD_S}$).

Table 15 – Altered Pixel Count (Lossless) – Grades

Pass	e.g., $M_{altered}(P_{SRC}, P_{E_SD_S})$ must equal 0
Fail	$M_{altered}(P_{SRC}, P_{E_SD_S})$ 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., $P_{E_SD_S}$) 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., $P_{E_SD_S}$) is compared to the peak pixel difference from its source image (P_{SRC}) processed through the pathway of the reference encoder and reference decoder ($P_{E_RD_R}$) 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 maximum reference measurement between 10:1 and 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.)	$M_{peak}(10{:}1, P_{E_SD_S}, P_{SRC})$
Reference Measurement @ 10:1	$M_{peak}(10{:}1, P_{E_RD_R}, P_{SRC})$
Reference Measurement @ 12:1	$M_{peak}(12{:}1, P_{E_RD_R}, P_{SRC})$
Primary Threshold	$\max(M_{peak}(10{:}1, P_{E_RD_R}, P_{SRC}), M_{peak}(12{:}1, P_{E_RD_R}, P_{SRC}))$
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	S0011_1000_08P-SRC.pgm	20	22	22
2	Flat	S0187_1000_07P-SRC.pgm	19	19	19
3	Flat	S0201_1000_02P-SRC.pgm	14	15	15
4	Flat	S0417_1000_11-SRC.pgm	17	18	18
5	Flat	S0464_1000_09P-SRC.pgm	15	17	17
6	Flat	S0564_1000_03P-SRC.pgm	26	25	26
7	Flat	S0586_1000_10P-SRC.pgm	18	22	22
8	Flat	S0676_1000_12-SRC.pgm	9	10	10
9	Flat	S0704_1000_05P-SRC.pgm	23	27	27
10	Flat	S0730_1000_04P-SRC.pgm	18	21	21
11	Rolled	S0051_1000_05-SRC.pgm	16	18	18
12	Rolled	S0093_1000_01-SRC.pgm	18	20	20
13	Rolled	S0152_1000_06-SRC.pgm	18	19	19
14	Rolled	S0176_1000_02-SRC.pgm	18	25	25
15	Rolled	S0249_1000_08-SRC.pgm	19	26	26
16	Rolled	S0342_1000_09-SRC.pgm	17	19	19
17	Rolled	S0397_1000_04-SRC.pgm	15	19	19
18	Rolled	S0503_1000_07-SRC.pgm	16	18	18
19	Rolled	S0705_1000_03-SRC.pgm	15	23	23
20	Rolled	S0724_1000_10-SRC.pgm	15	16	16
21	Slap	S0139_1000_13-SRC.pgm	16	21	21
22	Slap	S0286_1000_13-SRC.pgm	33	33	33
23	Slap	S0304_1000_14-SRC.pgm	15	21	21
24	Slap	S0392_1000_13-SRC.pgm	17	25	25
25	Slap	S0465_1000_14-SRC.pgm	19	20	20
26	Slap	S0466_1000_13-SRC.pgm	18	21	21
27	Slap	S0641_1000_14-SRC.pgm	16	18	18
28	Slap	S0795_1000_14-SRC.pgm	16	18	18
29	Slap	S0817_1000_13-SRC.pgm	25	26	26
30	Slap	S0850_1000_14-SRC.pgm	14	15	15

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., $P_{E_SD_S}$). Given a source image, $I^{\emptyset}$ (i.e., P_{SRC}), and a processed image, I^{δ}(e.g., $P_{E_SD_S}$), the image mean squared difference is defined as

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

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., $P_{E_SD_S}$) 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 ($P_{E_RD_R}$) 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 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.)	$M_{MSD}(10{:}1, P_{E_SD_S}, P_{SRC})$
Reference Measurement @ 10:1	$M_{MSD}(10{:}1, P_{E_RD_R}, P_{SRC})$
Reference Measurement @ 12:1	$M_{MSD}(12{:}1, P_{E_RD_R}, P_{SRC})$
Margin	$M_{MSD}(12{:}1, P_{E_RD_R}, P_{SRC}) - M_{MSD}(10{:}1, P_{E_RD_R}, P_{SRC})$
Primary Tolerance	25 % Margin
Secondary Tolerance	50 % Margin
Primary Threshold	$M_{MSD}(10{:}1, P_{E_RD_R}, P_{SRC})$ + Primary Tolerance
Secondary Threshold	$M_{MSD}(10{:}1, P_{E_RD_R}, P_{SRC})$ + Secondary Tolerance
Gold (Pass)	< $M_{MSD}(10{:}1, P_{E_RD_R}, P_{SRC})$
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	S0011_1000_08P-SRC.pgm	7.566	9.944	8.161	8.755
2	Flat	S0187_1000_07P-SRC.pgm	5.420	6.776	5.759	6.098
3	Flat	S0201_1000_02P-SRC.pgm	4.539	5.782	4.850	5.161
4	Flat	S0417_1000_11-SRC.pgm	5.799	7.269	6.167	6.534
5	Flat	S0464_1000_09P-SRC.pgm	6.536	8.101	6.927	7.319
6	Flat	S0564_1000_03P-SRC.pgm	9.122	11.731	9.774	10.427
7	Flat	S0586_1000_10P-SRC.pgm	8.660	11.158	9.285	9.909
8	Flat	S0676_1000_12-SRC.pgm	1.977	2.330	2.065	2.154
9	Flat	S0704_1000_05P-SRC.pgm	8.521	11.239	9.201	9.880
10	Flat	S0730_1000_04P-SRC.pgm	6.793	8.852	7.308	7.823
11	Rolled	S0051_1000_05-SRC.pgm	4.765	6.090	5.096	5.428
12	Rolled	S0093_1000_01-SRC.pgm	5.233	6.626	5.581	5.930
13	Rolled	S0152_1000_06-SRC.pgm	5.965	7.427	6.331	6.696
14	Rolled	S0176_1000_02-SRC.pgm	6.589	8.005	6.943	7.297
15	Rolled	S0249_1000_08-SRC.pgm	6.715	8.493	7.160	7.604
16	Rolled	S0342_1000_09-SRC.pgm	6.289	7.733	6.650	7.011
17	Rolled	S0397_1000_04-SRC.pgm	5.896	7.271	6.240	6.584
18	Rolled	S0503_1000_07-SRC.pgm	5.553	6.936	5.899	6.245
19	Rolled	S0705_1000_03-SRC.pgm	4.756	6.131	5.100	5.444
20	Rolled	S0724_1000_10-SRC.pgm	4.924	6.252	5.256	5.588
21	Slap	S0139_1000_13-SRC.pgm	3.607	4.808	3.907	4.208
22	Slap	S0286_1000_13-SRC.pgm	8.383	11.081	9.058	9.732
23	Slap	S0304_1000_14-SRC.pgm	2.390	3.149	2.580	2.770
24	Slap	S0392_1000_13-SRC.pgm	3.071	4.012	3.306	3.542
25	Slap	S0465_1000_14-SRC.pgm	4.143	5.449	4.470	4.796
26	Slap	S0466_1000_13-SRC.pgm	3.350	4.457	3.627	3.904
27	Slap	S0641_1000_14-SRC.pgm	2.603	3.319	2.782	2.961
28	Slap	S0795_1000_14-SRC.pgm	3.282	4.123	3.492	3.703
29	Slap	S0817_1000_13-SRC.pgm	4.818	6.212	5.167	5.515
30	Slap	S0850_1000_14-SRC.pgm	2.596	3.266	2.764	2.931

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.

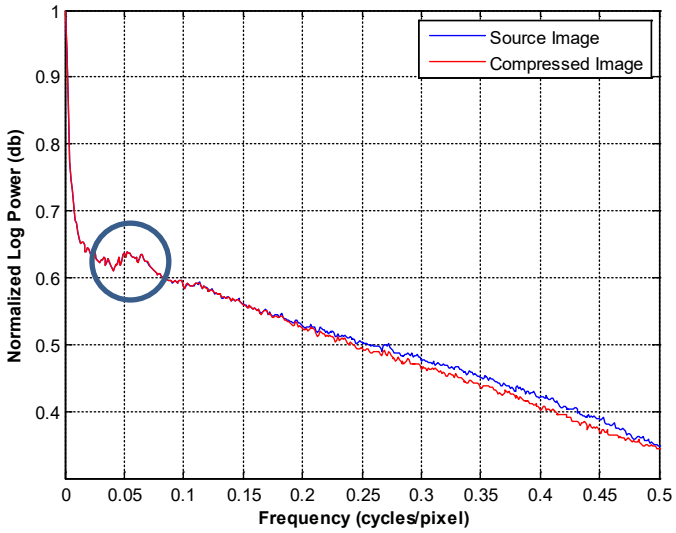

Figure 2 – SIVV signal of a fingerprint image before and after JPEG 2000 lossy compression

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., $P_{E_SD_S}$). 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., $P_{E_SD_S}$), 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:

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

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., $P_{E_SD_S}$) 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 ($P_{E_RD_R}$) 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 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	S0011_1000_08P-SRC.pgm	0.0049	0.0068	0.0054	0.0059
2	Flat	S0187_1000_07P-SRC.pgm	0.0057	0.0079	0.0063	0.0068
3	Flat	S0201_1000_02P-SRC.pgm	0.0068	0.0102	0.0077	0.0085
4	Flat	S0417_1000_11-SRC.pgm	0.0040	0.0051	0.0043	0.0046
5	Flat	S0464_1000_09P-SRC.pgm	0.0066	0.0073	0.0068	0.0070
6	Flat	S0564_1000_03P-SRC.pgm	0.0058	0.0120	0.0074	0.0089
7	Flat	S0586_1000_10P-SRC.pgm	0.0044	0.0070	0.0051	0.0057
8	Flat	S0676_1000_12-SRC.pgm	0.0077	0.0086	0.0079	0.0082
9	Flat	S0704_1000_05P-SRC.pgm	0.0094	0.0166	0.0112	0.0130
10	Flat	S0730_1000_04P-SRC.pgm	0.0041	0.0094	0.0054	0.0068
11	Rolled	S0051_1000_05-SRC.pgm	0.0080	0.0103	0.0086	0.0092
12	Rolled	S0093_1000_01-SRC.pgm	0.0109	0.0136	0.0116	0.0123
13	Rolled	S0152_1000_06-SRC.pgm	0.0064	0.0079	0.0068	0.0072
14	Rolled	S0176_1000_02-SRC.pgm	0.0095	0.0110	0.0099	0.0103
15	Rolled	S0249_1000_08-SRC.pgm	0.0071	0.0141	0.0089	0.0106
16	Rolled	S0342_1000_09-SRC.pgm	0.0078	0.0094	0.0082	0.0086
17	Rolled	S0397_1000_04-SRC.pgm	0.0094	0.0108	0.0098	0.0101
18	Rolled	S0503_1000_07-SRC.pgm	0.0087	0.0104	0.0091	0.0096
19	Rolled	S0705_1000_03-SRC.pgm	0.0104	0.0128	0.0110	0.0116
20	Rolled	S0724_1000_10-SRC.pgm	0.0100	0.0123	0.0106	0.0112
21	Slap	S0139_1000_13-SRC.pgm	0.0028	0.0035	0.0030	0.0032
22	Slap	S0286_1000_13-SRC.pgm	0.0034	0.0047	0.0037	0.0041
23	Slap	S0304_1000_14-SRC.pgm	0.0040	0.0064	0.0046	0.0052
24	Slap	S0392_1000_13-SRC.pgm	0.0027	0.0033	0.0029	0.0030
25	Slap	S0465_1000_14-SRC.pgm	0.0029	0.0056	0.0036	0.0043
26	Slap	S0466_1000_13-SRC.pgm	0.0044	0.0047	0.0045	0.0046
27	Slap	S0641_1000_14-SRC.pgm	0.0038	0.0060	0.0044	0.0049
28	Slap	S0795_1000_14-SRC.pgm	0.0096	0.0129	0.0104	0.0113
29	Slap	S0817_1000_13-SRC.pgm	0.0049	0.0066	0.0053	0.0058
30	Slap	S0850_1000_14-SRC.pgm	0.0038	0.0054	0.0042	0.0046

6. 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 (Section 6.1), downloading the NIST reference fingerprint image set (Section 6.2); running the NIST images through the supplier's CODEC and storing the resulting images (Section 6.3); submitting the supplier's CODEC images to NIST for evaluation (Section 6.4).

6.1. 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:

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

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

Organization 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.

6.2. Downloading NIST Reference Fingerprint Image Set

The supplier must download a version of the NIST Reference Fingerprint Image Set prepared for use in the conformance test and referred to as the JPEG 2000 Conformance Dataset (J2CD) from NIST. A link to download the NIST J2CD will be provided by NIST in response to the request for NIST assigned vendor identifier (see 6.1).

The reference fingerprint data set will be archived within a portable ZIP format[7] 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_{ER}) 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 22. 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.

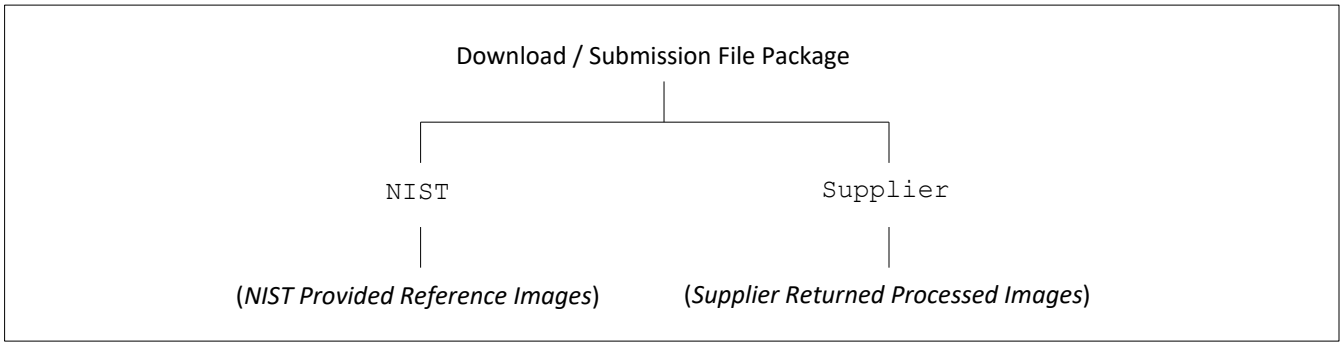

Figure 3 – Download / Submission File Package

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

Table 22 – NIST JPEG 2000 Conformance Dataset Files

SOURCE FILE	10:1 PROCESSED FILE (E_R)	LOSSLESS PROCESSED FILE (E_R)
S0011_1000_08P-SRC.pgm	S0011_1000_08P-ER.jp2	S0011_1000_08P-LER.jp2
S0187_1000_07P-SRC.pgm	S0187_1000_07P-ER.jp2	S0187_1000_07P-LER.jp2
S0201_1000_02P-SRC.pgm	S0201_1000_02P-ER.jp2	S0201_1000_02P-LER.jp2
S0417_1000_11-SRC.pgm	S0417_1000_11-ER.jp2	S0417_1000_11-LER.jp2
S0464_1000_09P-SRC.pgm	S0464_1000_09P-ER.jp2	S0464_1000_09P-LER.jp2
S0564_1000_03P-SRC.pgm	S0564_1000_03P-ER.jp2	S0564_1000_03P-LER.jp2
S0586_1000_10P-SRC.pgm	S0586_1000_10P-ER.jp2	S0586_1000_10P-LER.jp2
S0676_1000_12-SRC.pgm	S0676_1000_12-ER.jp2	S0676_1000_12-LER.jp2
S0704_1000_05P-SRC.pgm	S0704_1000_05P-ER.jp2	S0704_1000_05P-LER.jp2
S0730_1000_04P-SRC.pgm	S0730_1000_04P-ER.jp2	S0730_1000_04P-LER.jp2
S0051_1000_05-SRC.pgm	S0051_1000_05-ER.jp2	S0051_1000_05-LER.jp2
S0093_1000_01-SRC.pgm	S0093_1000_01-ER.jp2	S0093_1000_01-LER.jp2
S0152_1000_06-SRC.pgm	S0152_1000_06-ER.jp2	S0152_1000_06-LER.jp2
S0176_1000_02-SRC.pgm	S0176_1000_02-ER.jp2	S0176_1000_02-LER.jp2
S0249_1000_08-SRC.pgm	S0249_1000_08-ER.jp2	S0249_1000_08-LER.jp2
S0342_1000_09-SRC.pgm	S0342_1000_09-ER.jp2	S0342_1000_09-LER.jp2
S0397_1000_04-SRC.pgm	S0397_1000_04-ER.jp2	S0397_1000_04-LER.jp2
S0503_1000_07-SRC.pgm	S0503_1000_07-ER.jp2	S0503_1000_07-LER.jp2
S0705_1000_03-SRC.pgm	S0705_1000_03-ER.jp2	S0705_1000_03-LER.jp2
S0724_1000_10-SRC.pgm	S0724_1000_10-ER.jp2	S0724_1000_10-LER.jp2
S0139_1000_13-SRC.pgm	S0139_1000_13-ER.jp2	S0139_1000_13-LER.jp2
S0286_1000_13-SRC.pgm	S0286_1000_13-ER.jp2	S0286_1000_13-LER.jp2
S0304_1000_14-SRC.pgm	S0304_1000_14-ER.jp2	S0304_1000_14-LER.jp2
S0392_1000_13-SRC.pgm	S0392_1000_13-ER.jp2	S0392_1000_13-LER.jp2
S0465_1000_14-SRC.pgm	S0465_1000_14-ER.jp2	S0465_1000_14-LER.jp2
S0466_1000_13-SRC.pgm	S0466_1000_13-ER.jp2	S0466_1000_13-LER.jp2
S0641_1000_14-SRC.pgm	S0641_1000_14-ER.jp2	S0641_1000_14-LER.jp2
S0795_1000_14-SRC.pgm	S0795_1000_14-ER.jp2	S0795_1000_14-LER.jp2
S0817_1000_13-SRC.pgm	S0817_1000_13-ER.jp2	S0817_1000_13-LER.jp2
S0850_1000_14-SRC.pgm	S0850_1000_14-ER.jp2	S0850_1000_14-LER.jp2

6.3. 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.

6.3.1. Preparing Files for Encoder Test 1 (E_S)

Referencing the tests in the order listed in this section, 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 23 lists the processed files that are to be generated by this stage and stored under the `Supplier` subdirectory.

Table 23 – Supplier Prepared Files for Encoder Test 1 (E_S)

10:1 PROCESSED FILE (E_S)	LOSSLESS PROCESSED FILE (E_S)
S0011_1000_08P-ES.jp2	S0011_1000_08P-LES.jp2
S0187_1000_07P-ES.jp2	S0187_1000_07P-LES.jp2
S0201_1000_02P-ES.jp2	S0201_1000_02P-LES.jp2
S0417_1000_11-ES.jp2	S0417_1000_11-LES.jp2
S0464_1000_09P-ES.jp2	S0464_1000_09P-LES.jp2
S0564_1000_03P-ES.jp2	S0564_1000_03P-LES.jp2
S0586_1000_10P-ES.jp2	S0586_1000_10P-LES.jp2
S0676_1000_12-ES.jp2	S0676_1000_12-LES.jp2
S0704_1000_05P-ES.jp2	S0704_1000_05P-LES.jp2
S0730_1000_04P-ES.jp2	S0730_1000_04P-LES.jp2
S0051_1000_05-ES.jp2	S0051_1000_05-LES.jp2
S0093_1000_01-ES.jp2	S0093_1000_01-LES.jp2
S0152_1000_06-ES.jp2	S0152_1000_06-LES.jp2
S0176_1000_02-ES.jp2	S0176_1000_02-LES.jp2
S0249_1000_08-ES.jp2	S0249_1000_08-LES.jp2
S0342_1000_09-ES.jp2	S0342_1000_09-LES.jp2
S0397_1000_04-ES.jp2	S0397_1000_04-LES.jp2
S0503_1000_07-ES.jp2	S0503_1000_07-LES.jp2
S0705_1000_03-ES.jp2	S0705_1000_03-LES.jp2
S0724_1000_10-ES.jp2	S0724_1000_10-LES.jp2
S0139_1000_13-ES.jp2	S0139_1000_13-LES.jp2
S0286_1000_13-ES.jp2	S0286_1000_13-LES.jp2
S0304_1000_14-ES.jp2	S0304_1000_14-LES.jp2
S0392_1000_13-ES.jp2	S0392_1000_13-LES.jp2
S0465_1000_14-ES.jp2	S0465_1000_14-LES.jp2
S0466_1000_13-ES.jp2	S0466_1000_13-LES.jp2
S0641_1000_14-ES.jp2	S0641_1000_14-LES.jp2
S0795_1000_14-ES.jp2	S0795_1000_14-LES.jp2
S0817_1000_13-ES.jp2	S0817_1000_13-LES.jp2
S0850_1000_14-ES.jp2	S0850_1000_14-LES.jp2

6.3.2. 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 23) 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 24 lists the processed files that are to be generated by this stage and stored under the `Supplier` subdirectory.

Table 24 – Supplier Prepared Files for Decoder Test 2 (E_SD_S)

10:1 PROCESSED FILE (E_SD_S)	LOSSLESS PROCESSED FILE (E_SD_S)
S0011_1000_08P-ESDS.pgm	S0011_1000_08P-LESDS.pgm
S0187_1000_07P-ESDS.pgm	S0187_1000_07P-LESDS.pgm
S0201_1000_02P-ESDS.pgm	S0201_1000_02P-LESDS.pgm
S0417_1000_11-ESDS.pgm	S0417_1000_11-LESDS.pgm
S0464_1000_09P-ESDS.pgm	S0464_1000_09P-LESDS.pgm
S0564_1000_03P-ESDS.pgm	S0564_1000_03P-LESDS.pgm
S0586_1000_10P-ESDS.pgm	S0586_1000_10P-LESDS.pgm
S0676_1000_12-ESDS.pgm	S0676_1000_12-LESDS.pgm
S0704_1000_05P-ESDS.pgm	S0704_1000_05P-LESDS.pgm
S0730_1000_04P-ESDS.pgm	S0730_1000_04P-LESDS.pgm
S0051_1000_05-ESDS.pgm	S0051_1000_05-LESDS.pgm
S0093_1000_01-ESDS.pgm	S0093_1000_01-LESDS.pgm
S0152_1000_06-ESDS.pgm	S0152_1000_06-LESDS.pgm
S0176_1000_02-ESDS.pgm	S0176_1000_02-LESDS.pgm
S0249_1000_08-ESDS.pgm	S0249_1000_08-LESDS.pgm
S0342_1000_09-ESDS.pgm	S0342_1000_09-LESDS.pgm
S0397_1000_04-ESDS.pgm	S0397_1000_04-LESDS.pgm
S0503_1000_07-ESDS.pgm	S0503_1000_07-LESDS.pgm
S0705_1000_03-ESDS.pgm	S0705_1000_03-LESDS.pgm
S0724_1000_10-ESDS.pgm	S0724_1000_10-LESDS.pgm
S0139_1000_13-ESDS.pgm	S0139_1000_13-LESDS.pgm
S0286_1000_13-ESDS.pgm	S0286_1000_13-LESDS.pgm
S0304_1000_14-ESDS.pgm	S0304_1000_14-LESDS.pgm
S0392_1000_13-ESDS.pgm	S0392_1000_13-LESDS.pgm
S0465_1000_14-ESDS.pgm	S0465_1000_14-LESDS.pgm
S0466_1000_13-ESDS.pgm	S0466_1000_13-LESDS.pgm
S0641_1000_14-ESDS.pgm	S0641_1000_14-LESDS.pgm
S0795_1000_14-ESDS.pgm	S0795_1000_14-LESDS.pgm
S0817_1000_13-ESDS.pgm	S0817_1000_13-LESDS.pgm
S0850_1000_14-ESDS.pgm	S0850_1000_14-LESDS.pgm

6.3.3. 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 23 under the `Supplier` subdirectory, no further action is required by the supplier in order to prepare for Decoder Test 3 (E_SD_R).

6.3.4. 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 22, 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 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 Decoder Test 4 (E_RD_S)

10:1 PROCESSED FILE (E_RD_S)	LOSSLESS PROCESSED FILE (E_RD_S)
S0011_1000_08P-ERDS.pgm	S0011_1000_08P-LERDS.pgm
S0187_1000_07P-ERDS.pgm	S0187_1000_07P-LERDS.pgm
S0201_1000_02P-ERDS.pgm	S0201_1000_02P-LERDS.pgm
S0417_1000_11-ERDS.pgm	S0417_1000_11-LERDS.pgm
S0464_1000_09P-ERDS.pgm	S0464_1000_09P-LERDS.pgm
S0564_1000_03P-ERDS.pgm	S0564_1000_03P-LERDS.pgm
S0586_1000_10P-ERDS.pgm	S0586_1000_10P-LERDS.pgm
S0676_1000_12-ERDS.pgm	S0676_1000_12-LERDS.pgm
S0704_1000_05P-ERDS.pgm	S0704_1000_05P-LERDS.pgm
S0730_1000_04P-ERDS.pgm	S0730_1000_04P-LERDS.pgm
S0051_1000_05-ERDS.pgm	S0051_1000_05-LERDS.pgm
S0093_1000_01-ERDS.pgm	S0093_1000_01-LERDS.pgm
S0152_1000_06-ERDS.pgm	S0152_1000_06-LERDS.pgm
S0176_1000_02-ERDS.pgm	S0176_1000_02-LERDS.pgm
S0249_1000_08-ERDS.pgm	S0249_1000_08-LERDS.pgm
S0342_1000_09-ERDS.pgm	S0342_1000_09-LERDS.pgm
S0397_1000_04-ERDS.pgm	S0397_1000_04-LERDS.pgm
S0503_1000_07-ERDS.pgm	S0503_1000_07-LERDS.pgm
S0705_1000_03-ERDS.pgm	S0705_1000_03-LERDS.pgm
S0724_1000_10-ERDS.pgm	S0724_1000_10-LERDS.pgm
S0139_1000_13-ERDS.pgm	S0139_1000_13-LERDS.pgm
S0286_1000_13-ERDS.pgm	S0286_1000_13-LERDS.pgm
S0304_1000_14-ERDS.pgm	S0304_1000_14-LERDS.pgm
S0392_1000_13-ERDS.pgm	S0392_1000_13-LERDS.pgm
S0465_1000_14-ERDS.pgm	S0465_1000_14-LERDS.pgm
S0466_1000_13-ERDS.pgm	S0466_1000_13-LERDS.pgm
S0641_1000_14-ERDS.pgm	S0641_1000_14-LERDS.pgm
S0795_1000_14-ERDS.pgm	S0795_1000_14-LERDS.pgm
S0817_1000_13-ERDS.pgm	S0817_1000_13-LERDS.pgm
S0850_1000_14-ERDS.pgm	S0850_1000_14-LERDS.pgm

6.4. 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 23 through Table 25. The submission package 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.

6.4.1. 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 https://www.nist.gov/programs-projects/biometric-compression-information for the most up-to-date information on the submission of processed image packages for evaluation.

6.4.2. 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.

6.4.3. 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.

7. References

7.1. Publications and Reports

CHAMBERS	Chambers, John; William Cleveland, Beat Kleiner, and Paul Tukey (1983). Graphical Methods for Data Analysis. Wadsworth
FITZPATRICK	Fitzpatrick, M. et al. 1994, “WSQ Compression / Decompression Algorithm Test Report”, IAI Annual Conference.
GALTON	Galton, F. (2005). *Finger prints*. Mineola, NY: Dover Publications. (Original work published 1892)
JAIN	Jain, A., “Pores and Ridges: High-Resolution Fingerprint Matching Using Level 3 Features”, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 29, No. 1, January 2007.
JASPER	JasPer Project JPEG 2000 library. http://www.ece.uvic.ca/~frodo/jasper/
JPEG	"T-REC-T.81 : Information technology – Digital compression and coding of continuous-tone still images – Requirements and guidelines". http://www.itu.int/rec/T-REC-T.81. Retrieved 2011-01-12.
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LIBERT	“A 1D Spectral Image Validation/Verification Metric for Fingerprints”. Libert, J.M.; Grantham, J.; Orandi, S. August 19, 2009. http://www.nist.gov/customcf/get_pdf.cfm?pub_id=903078. Retrieved 2011-01-12.
LIKERT	Likert, R. (1932). *A Technique for the Measurement of Attitudes,* Archives of Psychology 140, 55.
MTR1	"Profile for 1000 ppi Fingerprint Compression". Lepley, M.A. http://www.mitre.org/work/tech_papers/tech_papers_04/lepley_fingerprint/lepley_fingerprint.pdf. Retrieved 2011-01-11.
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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 26 – 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