Supplementary Methods and Validation

Shared pipeline specification, common-budget component experiments, paired inference and reproducibility records.

S1. Shared restoration pipeline

Input and visible evidence. JPEG inputs are decoded as RGB doubles in [0,1], resized without upsampling to a longest side of 256 pixels, and clipped to [0,1] after interpolation. All quality metrics use these floating-point reference and reconstructed images before PNG export. Preview PNGs are quantized for storage and are not reloaded as metric inputs. The pre-mask reference inside the missing region is excluded from endpoint extraction, the objective and donor selection.

Canny detection and endpoint selection. A grayscale proxy fills masked pixels with the nearest known grayscale value obtained by bwdist(~mask). MATLAB R2025b edge(proxy,'Canny') selects thresholds automatically; the actual low/high thresholds for every case are recorded in Context_audit.csv. Edges within the radius-one dilation of the mask are removed. Candidates lie in the exterior ring dilate(mask,4) minus dilate(mask,1), using strel('disk',r,0). They are sorted by descending gradient strength after Gaussian smoothing with sigma = 1 pixel, with the original column-major order retained for exact ties. Candidates are accepted if at least 8 pixels from every retained point, up to 12 points. An odd last point is discarded.

Tangents and color descriptors. For the smoothed proxy gradient (gx,gy), the endpoint tangent is (-gy,gx)/(norm((-gy,gx))+eps), reversed when its dot product with the vector toward the mask-pixel centroid is negative. A zero gradient therefore produces a zero tangent. The normal is (-ty,tx). Two descriptor centers are rounded at p - 2t - 3n and p - 2t + 3n, clipped to the image. Each side is the channel-wise mean over known pixels in its clipped 5-by-5 window. The two RGB triples form a six-component descriptor; a nonfinite component is set to zero.

Random keys and cubic curves. For n retained endpoints, d = max(2,2n) and all coordinates lie in [0,1]. The first n keys are sorted and adjacent indices are paired. MATLAB stable sorting gives an increasing original index for equal keys. For a pair (i,j), L = ||p_j-p_i||, B = p_i + (0.1+0.65u)Lt_i, C = p_j + (0.1+0.65v)Lt_j, and c(t) = (1-t)^3 p_i + 3(1-t)^2tB + 3(1-t)t^2C + t^3p_j. The objective uses M = 32 equally spaced samples, including both endpoints. n = 0 gives objective zero, no fabricated endpoints and a texture-only reconstruction.

Exact penalty definitions. Let K = n/2, a_i be the six-component endpoint descriptor, a_j^rev its two RGB halves exchanged, and h_ij = (p_j-p_i)/(||p_j-p_i||+eps). Let Delta c_l = c_(l+1)-c_l and Delta^2 c_l = Delta c_(l+1)-Delta c_l. The five implemented terms are:

(S1) $J_{color} = \frac{1}{K}\sum_{k=1}^{K} mean_{q=1,\ldots,6} |a_{iq} - a_{jq}{}^{rev}|$

(S2) $J_{tangent} = \frac{1}{K}\sum_{k=1}^{K} \frac{2 - t_i \cdot h_{ij} + t_j \cdot h_{ij}}{2}$

(S3) $J_{bending} = \frac{1}{K}\sum_{k=1}^{K} \frac{mean_l \|\Delta^2 c_l\|^2}{mean_l \|\Delta c_l\|^2 + \varepsilon}$

(S4) $J_{outside} = \frac{1}{K}\sum_{k=1}^{K}[1 - mean_{p \in L_k} mask(p) \cdot mean_l inside_{kl}]$

(S5) $J_{crossing} = \frac{1}{KM}\sum_{k=1}^{K}\sum_{p \in L_k \cap \Omega} 1\{p \, occupied \, before \, curve \, k\}$

Penalty scales and raster conventions. For the last two terms, samples 3 through M-2 are rounded. The pre-clipping inside flag tests image bounds; coordinates are then clipped to the image, and duplicate raster pixels form the set L_k. Occupancy is updated once per unique pixel per curve. Consequently, the crossing term counts sampled overlap with any earlier curve, rather than exact continuous curve intersections or every pairwise intersection. Color disagreement lies in [0,1]; tangent disagreement lies in [0,2]; the outside and normalized overlap terms lie in [0,1]. Bending is a nonnegative dimensionless ratio with no universal upper bound. All five terms are dimensionless; pixel coordinates enter geometry, but cancel in the bending ratio. The sampling

grid remains fixed when comparing algorithms. The objective is J = J_color + 0.6J_tangent + 0.25J_bending + 2J_outside + 0.5J_crossing. These terms are not standardized by per-image sample variances or fitted to hidden reference pixels.

Structure rasterization and initial guides. For filling, every 32-point curve is linearly interpolated to max(2,ceil(2 times polyline length)) points, then rounded to pixels. Only mask pixels are modified. The guide color interpolates linearly between the averages of the two side-color triples at each endpoint. Guided pixels become known and join the visible-edge barrier; overlapping guides are processed in decoded pair order.

Partitions and donor selection. Texture patches are 7-by-7 RGB arrays. Candidate donor centers lie on the stride-four grid and have patches completely outside the original mask and inside the image. If more than 384 are available, equally spaced indices of the ordered donor list retain 384. Donors remain fixed. Partitions are four-connected labels of the complement of the radius-one dilation of the visible and reconstructed barriers. At each step, unknown boundary pixels are ranked by the number of known pixels in their 7-by-7 neighborhood. The first column-major maximum is processed. Mean RGB squared difference on currently known entries selects a donor with the same nonzero center label, with the full donor pool used and counted when no such donor exists. Boundary crops use corresponding donor entries. Only unknown target entries are copied.

Degeneracies and failures. Equal minimum SSD values select the first donor. An empty intact donor pool raises an error instead of introducing an unreported fallback. Nonfinite image metrics and changes to known pixels also raise errors. Zero-endpoint cases remain in restoration summaries, but are identified as noninformative about structural optimizer performance. Their identically zero objective is not interpreted as successful structural recovery.

S2. Image-quality implementations

SSIM [36]. MATLAB R2025b ssim(rgb2gray(restored),rgb2gray(reference),'DynamicRange',1) is applied to grayscale doubles, with other options left at that release's defaults. It is a full-image measure, not a mask-restricted SSIM.

FSIM and FSIMc [37]. The bundled FeatureSIM.m is the authors' version 1.0, with input RGB doubles multiplied by 255. FSIM uses luminance and FSIMc also uses opponent chrominance. Constants T1 = 0.85, T2 = 160, T3 = T4 = 200 and chrominance exponent 0.03 are unchanged. Automatic averaging/downsampling uses max(1,round(min(height,width)/256)); here, it is 1. The embedded phase-congruency implementation uses four scales and four orientations.

SR-SIM [38]. The authors' bundled version 1.0 takes RGB values on [0,255], converts to luminance internally, and uses its automatic downsampling. C1 = 0.40, C2 = 225 and gradient exponent 0.50 are unchanged.

VSI [39]. The authors' bundled 2013 implementation takes RGB values on [0,255]. Its constants are VS = 1.27, GM = 386, chrominance = 130, alpha = 0.40, lambda = 0.020, sigmaF = 1.34, omega0 = 0.0210, sigmaD = 145, and sigmaC = 0.001. Its internal saliency, color transforms and downsampling are unmodified. Original copyright and research-use notices are retained in the source distribution. File SHA-256 fingerprints identify the exact files rather than implying a tagged repository release.

S3. Experimental design and inference

Common-budget factorial experiment. CEC2022 F1-F12 use d = 20 and bounds [-100,100] for every function, N = 30, T = 500 and 50 matched runs. Each externally counted search performs 15030 calls, including initialization. Eight on/off combinations of initialization, secant/tangent search and rescue are compared, alongside the supplied physical-coordinate HOA. The no-component internal control retains normalization and reflection, so it is labeled M000 rather than HOA. Five further comparators supply the seven-method inferential audit. Seeds are 20261101 + 1000f + r. Sharing a seed defines a matched block; initialization changes intentionally produce different populations when the initialization component changes.

Component effects. The full-versus-removal contrast is final objective without a component minus final objective with all three components; positive values favor full IHOA. A factorial main effect averages this difference over all four states of the other two components. A pairwise interaction is the negative second finite difference, averaged over the third component: positive values indicate an additional reduction beyond additivity on that function's raw objective scale. The three-way contrast is the negative third finite difference. Raw objectives are not averaged across different benchmark functions. Reported mean ranks average within-function ranks of method means, with average ranks assigned to exact ties.

Restoration design. The existing repeated experiment supplies 16 images, three independently seeded nested masks per damage level, ten optimizer runs per mask, and seven algorithms (10080 recorded solves). Component removal adds three variants on exactly these cases, masks and seeds (4320 new solves). N = 20, 30 and 50 with T = 100 gives 2020, 3030 and 5050 counted search calls at 5%, 20% and 30% missing area. Budgets are equal within a damage level. Across-level comparisons retain the population/budget limitation. Reconstruction control experiments add the best initial-population candidate with no search iterations and deterministic texture-only completion without optimized curves. These controls have N and zero objective calls, respectively; they are pipeline controls, not equal-budget optimizers.

Mask construction. For image width W and height H, the center is cx = W(0.38+0.24U1), cy = H(0.38+0.24U2), and phase = 2piU3, where the U values are uniform draws from the mask stream. With dx = (x-cx)/W, dy = (y-cy)/H and theta = atan2(dy,dx), pixels are ranked by (|dx|^4+|dy|^4)^(1/4)[1+0.08sin(5theta+phase)]. The first round(HWf) pixels form the mask at ratio f. Stable score sorting retains column-major order at exact ties. Reusing this ordering across damage levels gives nested masks; different mask seeds give separate configurations. Mask generation depends on seed, image dimensions and target fraction, not optimizer outcomes or image content.

Seeds and experimental units. The restoration base seed is 20261027. The mask seed is base + 1000000 + 1000i + m. The optimizer seed is base + 10000000 + 100000i + 1000m + 100g + r. Here i, m, g and r are one-based image, mask, damage-level and run indices. All algorithms within a matched block receive the same seed, mask and context. For inference, each image contributes one value after averaging its three masks and ten runs; the independent restoration unit is the image (n = 16), not the 480 individual solves.

Uncertainty and test families. Confidence intervals are percentile bootstrap intervals for the mean from 5000 resamples, with generator mt19937ar and bootstrap seed 6112026. Benchmark resampling uses the 50 matched run differences within a function; restoration resampling uses the 16 image-level paired differences. Two-sided exact conditional sign-permutation Wilcoxon signed-rank tests remove numerically zero differences and average tied absolute ranks. The null concerns a symmetric paired-difference distribution about zero; the alternative is two-sided. The zero tolerance is 10^-12 times max(1,absolute function optimum) for CEC and 10^-12 for restoration metrics. Rank-biserial effects are the signed sum of ranks divided by their total, positive in the stated benefit direction.

Multiplicity and interpretation. Holm adjustment is applied to separately defined scientific families: 72 IHOA-comparator/function tests, 36 full-versus-component-removal/function tests, 84 factorial-effect/function tests, nine restoration component-removal MaskPSNR tests, twelve retained-variant-versus-HOA MaskPSNR tests, and six reconstruction-control MaskPSNR tests. Secondary SSIM/FSIMc intervals and one-factor sensitivity results are descriptive. A two-sided significant difference is not automatically called an improvement; the observed effect direction is reported. Confidence intervals are pointwise, not simultaneous intervals for all comparisons.

Convergence and resources. Every supplementary convergence curve aggregates all 50 runs. The plotted ordinate is the mean of log10(max(best objective minus known optimum,10^-12)), and shading is a descriptive pointwise mean +/- 1.96 standard errors across runs. No run is selected for a favorable trajectory. The horizontal axis is measured search evaluations, from N to N(T+1). The primary queue uses four process workers with one computational thread per task. An auxiliary two-worker queue was checkpointed and paused because of memory pressure, then resumed with four workers after the primary queue. All scientific settings and seeds are unchanged on resumption. Both run on the documented CPU platform. Recorded elapsed times are descriptive under concurrent workloads and are not exclusive-machine speed measurements.

S4. Parameter rationale and targeted sensitivity

Literature-informed defaults. Stratification and distance-based space filling follow the design principles of McKay et al. [40] and Morris and Mitchell [41]. Ridge stabilization follows Hoerl and Kennard [42]. Local model construction and control of search scale are motivated by derivative-free optimization principles reviewed by Conn, Scheinberg and Vicente [43]. These references justify the mechanisms, not the exact numerical settings or convergence guarantees for IHOA. The coverage weight 0.1, ridge coefficient 0.001, step coefficients and rescue constants are fixed experience-based implementation choices. The five structural weights are also heuristic trade-offs within the shared structure-priority model; they are not numerical values claimed to have been prescribed by these sources.

Targeted numerical tests. One factor at a time is varied around the unchanged defaults: ordering weight {0,0.05,0.1,0.2}; ridge {0.0001,0.001,0.01}; and a multiplier {0.5,1,1.5} on the regular-step schedule. Each setting uses the same 12 functions, N = 30, T = 500 and first 25 matched seeds of the new benchmark protocol. Each of the five structural weights is separately halved and doubled, using all 16 images, all three damage levels, the fixed first mask and first five optimizer seeds. MaskPSNR assesses these changes because raw structural objectives with different weights are not directly comparable.

Development and evaluation. The additional sensitivity study is retrospective and uses the reported benchmark/image cases; it is not an independent tuning-validation split. The original defaults are retained regardless of which tested setting has the best observed mean. The sensitivity results therefore characterize dependence on the tested values and do not establish optimal parameter choices or robustness to all possible interactions. The pre-existing rescue-threshold, neighborhood-size and rescue-radius studies remain distinct from this additional protocol.

S5. Provenance, generated pixels and scope

Dataset provenance and attribution. The upstream source is the DhMurals1714 collection released with Li et al. [44], with the dataset hosted in the authors' project repository [45]. The repository describes 525 digitally photographed murals and 1189 scanned artistic replicas. The supplied archive has a 50-image test split; sixteen files were selected by equally spaced indices of its lexicographically sorted filenames. Selected_images_and_provenance.csv records exact names, source archive entries, dimensions and hashes. Individual photographer/artist identities, cave identifiers, capture dates and photograph-versus-replica labels are not established by the supplied file manifest.

Reuse permissions. The inspected dataset archive contains no image-level rights or license manifest, and the inspected original repository does not supply a dataset-specific reuse license. Public availability is not presented as evidence that all images are in the public domain, Creative Commons licensed or cleared for redistribution. Attribution to the dataset authors does not replace attribution or permission required by original photographers, artists or holding institutions. This data supplement grants no additional image rights; publication and redistribution permissions require author verification with the relevant rights holders. The reported dataset source is distinguished from image-specific ownership.

Generated-region documentation. The original reference, damaged input, binary generated-region mask, fixed-run completion, optimizer seed fingerprint are kept as separate records. The mask identifies every computationally filled pixel, and references are not overwritten. For complete IHOA, the ten saved decision vectors for each fixed image-mask-ratio case are reconstructed to produce per-channel sample standard deviations. The scalar map is sqrt(mean_RGB(variance)); known-pixel variability is checked to be zero. Raw maps and the associated masks and seeds are retained. Figure S3 uses the preselected first image, first mask and fixed run 1 rather than a best-looking run.

Meaning of uncertainty and sustainability. Across-run pixel variability measures sensitivity to optimizer randomness conditional on the fixed image, mask and reconstruction model. It is not a calibrated probability of correctness, a historical authenticity map, or a complete representation of model and provenance uncertainty. Artificially masked reference reconstruction, structural fitness and runtime behavior are the measured outcomes. Conservation-specific reliability, curatorial assessment, physical preservation, long-term access, public engagement and environmental sustainability outcomes are not experimentally established. Those heritage applications remain proposed uses requiring independent evidence and expert assessment.

S6. Supplementary experimental results

IHOA achieves a lower mean objective than HOA on 12 of the 12 functions under the common evaluation budget, with 11 comparisons favoring IHOA after Holm adjustment. In the supplementary factorial experiment, IHOA has an average rank of 3.83, while the lowest observed average rank is 3.17 for M110. The comparison separates the physical-coordinate HOA reference from M000, which retains normalized updates and reflection. The effect of each component is therefore assessed within a common implementation rather than inferred solely from its difference from HOA. Per-function full-versus-removal and factorial main/interaction contrasts are reported with paired confidence intervals; a component is not assumed to improve every function or to combine additively with the others.

The seven-method paired inferential audit contains 72 two-sided comparisons, of which 33 favor IHOA and 20 favor a comparator after Holm adjustment; the remaining 19 do not meet the adjusted 0.05 threshold. Adjusted probabilities, rank-biserial effects, zero/tie handling and paired mean-difference intervals are supplied for every comparison. Figure S1 aggregates all 50 trajectories against objective evaluations, using a mean log-error curve and pointwise uncertainty bands. These new records form a separate reproducible validation; they are not substituted for the numerical values in the original tables.

Across the nine primary restoration component-removal comparisons, zero favor complete IHOA and zero favor a component-removed variant after Holm adjustment. The remaining nine comparisons are not statistically distinguishable at the adjusted threshold. Table S4 reports the direction and size of every difference, including cases where removal yields the higher observed mean. The independent unit is the image: each of the sixteen image-level values averages three masks and ten runs. The retained differences from HOA are separately reported, so a nonsignificant full-versus-removal result is not presented as proof that a component is necessary.

The pipeline-control experiment compares the complete method with the best initialized candidate before iterative search and with texture-only completion. Of six MaskPSNR contrasts, two favor complete IHOA and zero favor a control after Holm adjustment. These controls quantify the contribution of the optimized structural stage within this particular pipeline, rather than establishing a new exemplar-filling method. Their objective-call counts are N and zero, respectively, and are explicitly distinguished from the full optimization budget. Low structural fitness is evaluated separately from reference-image fidelity and is not taken as evidence of historical correctness.

In the additional coefficient sensitivity experiment, the unchanged default has an average rank of 3.42, and the lowest observed average rank among the tested settings is 3.17 for Coverage005. The weight, regularization and step-scale results, and structural-weight perturbations are reported without replacing the defaults with a retrospectively selected winner. The analysis describes dependence over the tested ranges; it does not establish that the chosen numbers are globally optimal or that interactions outside the tested one-factor changes are negligible.

Table S1. Component configurations and observed average ranks; smaller ranks are better.

Variant	Initialization/search/rescue	Mean rank
HOA	External physical-coordinate baseline	8.67
M000	0/0/0	6.83
M100	1/0/0	6.33
M010	0/1/0	3.33
M001	0/0/1	4.67
M110	1/1/0	3.17
M101	1/0/1	4.50
M011	0/1/1	3.67
IHOA	1/1/1	3.83

Table S2. Full-IHOA benefit over each component-removed version on CEC2022. Positive values favor full IHOA. Entries are paired means [95% CI].

Function	Remove initialization	Remove search	Remove rescue
F1	-2.5462 [-9.2008, 3.9388]	281.9349 [221.5002, 351.7274]	-29.3290 [-36.5605, -21.3224]
F2	-2.8868 [-7.9392, 2.1919]	-1.5499 [-6.0548, 2.8662]	-4.0208 [-7.5560, -1.3676]
F3	-1.4055 [-5.3816, 2.7437]	-4.4555 [-9.3355, 0.3328]	0.1117 [-2.9332, 3.3329]
F4	2.9459 [-4.1690, 9.9748]	16.6400 [9.8507, 23.4613]	-2.0191 [-3.8234, -0.2174]
F5	-17.5689 [-255.8971, 226.3212]	371.7666 [127.8286, 637.7616]	14.5941 [-99.1195, 125.6965]
F6	1.494e+04 [-1.326e+04, 4.280e+04]	2.185e+05 [1.716e+05, 2.658e+05]	-1.043e+05 [-1.235e+05, -8.728e+04]

Function	Remove initialization	Remove search	Remove rescue
F7	-0.8363 [-21.8778, 21.1600]	34.6085 [13.2859, 56.1846]	-11.4728 [-19.4804, -4.3175]
F8	8.5488 [-15.0629, 31.5826]	-20.5924 [-40.8919, -0.3710]	5.3014 [-3.6147, 16.6184]
F9	-0.0836 [-0.2032, 0.0384]	2.3661 [1.9783, 2.8011]	-0.5301 [-0.6304, -0.4379]
F10	225.3803 [-295.9247, 727.8827]	-270.2796 [-690.9495, 129.5095]	316.9133 [79.6348, 576.6465]
F11	-18.3433 [-55.1572, 16.5476]	1.0017 [-28.2818, 29.5676]	-27.2541 [-32.1658, -22.3412]
F12	37.7303 [-3.2597, 79.8805]	-63.5178 [-87.0828, -39.4303]	184.2773 [134.7542, 237.9022]

The full 84 main/interaction effect records and their 84-test Holm family are in CEC_factorial_effects.csv. These raw objective contrasts are interpreted within each function, not averaged across function scales.

Table S3. Restoration component ablation. MaskPSNR entries are mean [95% CI] over sixteen image-level means; SSIM and FSIMc entries are means.

Missing	Variant	MaskPSNR (dB)	SSIM	FSIMc
5%	HOA	14.7069 [12.7242, 17.5448]	0.9590	0.9714
5%	IHOA	14.7300 [12.7225, 17.4096]	0.9591	0.9715
5%	WithoutInit	14.7637 [12.8049, 17.5503]	0.9592	0.9717
5%	WithoutSearch	14.7282 [12.7311, 17.5187]	0.9591	0.9715
5%	WithoutRescue	14.6784 [12.6860, 17.4926]	0.9591	0.9714
20%	HOA	13.3306 [12.0834, 14.7386]	0.8364	0.8919
20%	IHOA	13.3497 [12.0692, 14.7522]	0.8367	0.8921
20%	WithoutInit	13.3470 [12.0919, 14.7296]	0.8366	0.8923
20%	WithoutSearch	13.3147 [12.0612, 14.7937]	0.8364	0.8918
20%	WithoutRescue	13.3853 [12.1234, 14.8302]	0.8369	0.8922
30%	HOA	12.9791 [11.9445, 14.1300]	0.7543	0.8444
30%	IHOA	12.9961 [11.9467, 14.1634]	0.7546	0.8447
30%	WithoutInit	13.0103 [11.9486, 14.1563]	0.7548	0.8447
30%	WithoutSearch	12.9820 [11.9389, 14.1628]	0.7545	0.8443
30%	WithoutRescue	13.0057 [11.9333, 14.1832]	0.7545	0.8449

Table S4. Paired MaskPSNR component-removal effects; full minus removed. The primary family contains nine tests.

Missing	Removed variant	Full benefit (dB) [95% CI]	Holm p	Rank effect
5%	WithoutInit	-0.0337 [-0.0906, 0.0137]	1.0000	-0.300
5%	WithoutSearch	0.0017 [-0.0571, 0.0618]	1.0000	-0.050
5%	WithoutRescue	0.0516 [0.0083, 0.0986]	0.6570	0.533
20%	WithoutInit	0.0027 [-0.0576, 0.0546]	1.0000	0.206
20%	WithoutSearch	0.0350 [-0.0272, 0.0946]	1.0000	0.294
20%	WithoutRescue	-0.0356 [-0.0881, 0.0166]	1.0000	-0.353
30%	WithoutInit	-0.0142 [-0.0557, 0.0275]	1.0000	-0.147
30%	WithoutSearch	0.0141 [-0.0274, 0.0595]	1.0000	0.103

Missing	Removed variant	Full benefit (dB) [95% CI]	Holm p	Rank effect
30%	WithoutRescue	-0.0096 [-0.0388, 0.0165]	1.0000	-0.118

Table S5. Corrected supplementary seven-method inference. Each cell is Holm-adjusted p/rank-biserial effect. Positive effects favor IHOA; all tests are two-sided.

Function	HOA	EDO	GWO	GA	PSO	ALA
F1	1.279e-13 1.000	1.279e-13 1.000	1.279e-13 1.000	1.279e-13 1.000	1.279e-13 1.000	1.279e-13 1.000
F2	1.279e-13 1.000	1.279e-13 1.000	2.570e-11 0.969	1.384e-12 0.989	0.6017 0.330	1.0000 -0.236
F3	0.0004 0.663	1.0000 0.170	7.461e-13 -0.992	1.279e-13 -1.000	1.279e-13 -1.000	1.279e-13 -1.000
F4	1.279e-13 1.000	1.279e-13 1.000	1.0000 -0.189	1.279e-13 1.000	0.6135 -0.322	0.6017 -0.338
F5	4.014e-09 0.912	1.281e-08 0.895	0.0013 -0.627	2.345e-13 0.997	3.055e-12 -0.984	3.771e-10 -0.942
F6	1.279e-13 1.000	1.279e-13 1.000	0.8135 0.291	1.279e-13 1.000	8.467e-06 -0.769	1.279e-13 -1.000
F7	0.6017 0.338	1.0000 0.046	0.0001 -0.699	1.0000 0.024	2.282e-09 -0.920	1.149e-07 -0.859
F8	0.0098 0.551	1.0000 -0.081	1.0000 -0.073	0.4833 0.358	1.0000 -0.071	0.0719 -0.464
F9	1.279e-13 1.000	1.279e-13 1.000	1.279e-13 1.000	1.279e-13 1.000	1.236e-06 0.812	1.279e-13 -1.000
F10	0.0003 0.671	0.6017 0.341	1.0000 -0.189	9.712e-07 -0.818	0.0018 -0.614	1.0000 -0.100
F11	1.279e-13 1.000	1.279e-13 1.000	1.279e-13 1.000	1.279e-13 1.000	4.111e-07 0.835	0.7449 -0.304
F12	1.279e-13 1.000	4.208e-08 -0.876	3.618e-11 -0.965	1.066e-08 -0.898	1.015e-06 -0.816	2.345e-13 -0.997

Table S6. Structural objective and failure audit of the existing repeated restoration records. Fitness values are pooled descriptive means, not image-quality scores.

Missing	Algorithm	Initial J	Final J	Zero J runs	No improvement	Numerical failures
5%	ALA	0.5339	0.3688	30	30	0
5%	EDO	0.5339	0.4063	30	31	0
5%	GA	0.5339	0.4072	30	30	0
5%	GWO	0.5339	0.3683	30	30	0
5%	HOA	0.5339	0.3860	30	30	0
5%	IHOA	0.5348	0.3868	30	30	0
5%	PSO	0.5339	0.3648	30	30	0
20%	ALA	0.5850	0.4169	0	0	0

Missing	Algorithm	Initial J	Final J	Zero J runs	No improvement	Numerical failures
20%	EDO	0.5850	0.4471	0	1	0
20%	GA	0.5850	0.4535	0	0	0
20%	GWO	0.5850	0.4204	0	0	0
20%	HOA	0.5850	0.4327	0	1	0
20%	IHOA	0.5822	0.4360	0	0	0
20%	PSO	0.5850	0.4158	0	0	0
30%	ALA	0.5306	0.3852	0	0	0
30%	EDO	0.5306	0.4120	0	1	0
30%	GA	0.5306	0.4115	0	0	0
30%	GWO	0.5306	0.3881	0	1	0
30%	HOA	0.5306	0.4033	0	0	0
30%	IHOA	0.5329	0.4053	0	0	0
30%	PSO	0.5306	0.3889	0	0	0

Each algorithm has 480 solves per ratio. The 210 zero trajectories arise from three zero-endpoint contexts (image 150-0-1.jpg, 5%, masks 1-3). They are reported separately from failed execution and lack of strict improvement.

Table S7. Structural-stage controls. Complete-IHOA minus control MaskPSNR uses sixteen paired image means and a six-test Holm family.

Missing	Control	Control MaskPSNR [95% CI]	Full benefit [95% CI]	Holm p
5%	InitialPopulationOnly	14.6175 [12.6292, 17.4398]	0.1125 [0.0350, 0.1953]	0.0603
5%	TextureOnly	13.8489 [11.6626, 16.7857]	0.8811 [0.4389, 1.4495]	0.0070
20%	InitialPopulationOnly	13.3017 [12.0032, 14.7144]	0.0480 [-0.0140, 0.1137]	0.5784
20%	TextureOnly	12.9993 [11.6270, 14.3736]	0.3504 [0.1173, 0.6545]	0.0381
30%	InitialPopulationOnly	13.0287 [11.9356, 14.2424]	-0.0326 [-0.0977, 0.0317]	0.8664
30%	TextureOnly	12.9669 [11.6502, 14.3184]	0.0292 [-0.3759, 0.5161]	0.8664

The initial-population control retains refined initialization and chooses its best evaluated candidate without any search iteration (N objective calls). Texture-only uses no structural objective calls and is deterministic within each mask. These controls are not presented as equal-budget competing optimizers.

Table S8. Targeted coefficient sensitivity: average ranks of per-function means over 25 matched runs; lower is better.

Setting	Average rank
Default	3.42
Coverage0	4.92
Coverage005	3.17
Coverage02	4.25
Ridge0001	5.50
Ridge001	4.33
Step05	5.08
Step15	5.33

Defaults are retained even if another setting has the best observed mean. Per-function paired changes and intervals are in Coefficient_sensitivity_summary.csv.

Table S9. Structural-weight sensitivity: fixed first mask, five runs per image. Values are means [95% CI] over sixteen image-level means. Changes are relative to the unchanged default.

Missing	Setting	MaskPSNR (dB) [95% CI]	Change from default [95% CI]
5%	Default	14.8593 [12.7492, 18.0429]	0.0000 [0.0000, 0.0000]
5%	Color_x0.5	14.7928 [12.5806, 18.0325]	-0.0665 [-0.2804, 0.1233]
5%	Color_x2	14.8074 [12.5586, 18.0814]	-0.0520 [-0.2899, 0.2282]
5%	Tangent_x0.5	14.8158 [12.6346, 18.0962]	-0.0435 [-0.2342, 0.1484]
5%	Tangent_x2	14.8526 [12.7345, 18.0345]	-0.0067 [-0.1070, 0.0920]
5%	Bending_x0.5	14.8321 [12.7375, 18.0447]	-0.0272 [-0.1869, 0.1395]
5%	Bending_x2	14.8195 [12.6572, 18.0759]	-0.0398 [-0.2164, 0.1400]
5%	Outside_x0.5	14.8060 [12.6916, 18.0714]	-0.0533 [-0.2053, 0.0948]
5%	Outside_x2	14.7720 [12.5697, 17.9528]	-0.0873 [-0.2151, 0.0312]
5%	Crossing_x0.5	14.9451 [12.7982, 18.2336]	0.0858 [-0.0714, 0.2626]
5%	Crossing_x2	14.7467 [12.6387, 17.9479]	-0.1126 [-0.2618, 0.0432]
20%	Default	13.6505 [12.2849, 15.5017]	0.0000 [0.0000, 0.0000]
20%	Color_x0.5	13.6534 [12.3609, 15.4667]	0.0029 [-0.1385, 0.1631]
20%	Color_x2	13.6112 [12.2579, 15.4328]	-0.0392 [-0.1704, 0.0920]
20%	Tangent_x0.5	13.5795 [12.2324, 15.3507]	-0.0709 [-0.1391, 0.0028]
20%	Tangent_x2	13.6079 [12.3211, 15.3391]	-0.0426 [-0.1908, 0.0876]
20%	Bending_x0.5	13.6954 [12.3286, 15.5097]	0.0449 [-0.0252, 0.1158]
20%	Bending_x2	13.6618 [12.2968, 15.4833]	0.0114 [-0.0758, 0.0994]
20%	Outside_x0.5	13.6362 [12.2927, 15.5178]	-0.0142 [-0.0863, 0.0520]
20%	Outside_x2	13.6655 [12.3031, 15.4535]	0.0150 [-0.0916, 0.1305]
20%	Crossing_x0.5	13.6549 [12.3211, 15.5244]	0.0044 [-0.0733, 0.0811]
20%	Crossing_x2	13.6025 [12.2710, 15.3876]	-0.0480 [-0.1959, 0.1085]
30%	Default	13.1867 [11.9469, 14.7752]	0.0000 [0.0000, 0.0000]
30%	Color_x0.5	13.1616 [11.9447, 14.7428]	-0.0251 [-0.1344, 0.0890]
30%	Color_x2	13.2495 [12.0682, 14.7648]	0.0627 [-0.0962, 0.2362]
30%	Tangent_x0.5	13.2183 [12.0098, 14.7773]	0.0315 [-0.0434, 0.1129]
30%	Tangent_x2	13.1569 [11.9207, 14.6952]	-0.0298 [-0.1279, 0.0705]
30%	Bending_x0.5	13.1894 [11.9550, 14.7667]	0.0027 [-0.0768, 0.0743]
30%	Bending_x2	13.1791 [11.9711, 14.7168]	-0.0077 [-0.1165, 0.0976]
30%	Outside_x0.5	13.1281 [11.9369, 14.6091]	-0.0587 [-0.2419, 0.1173]
30%	Outside_x2	13.1333 [11.9084, 14.7237]	-0.0534 [-0.1510, 0.0365]
30%	Crossing_x0.5	13.1174 [11.9018, 14.6889]	-0.0694 [-0.1625, 0.0221]
30%	Crossing_x2	13.1774 [11.9725, 14.6795]	-0.0093 [-0.1242, 0.0855]

Table S10. Exact selected image identifiers. Image-level photograph/replica classifications and rights-holder identities are not inferred from filenames.

Case	Filename	Original dimensions
1	000098.jpg	720 x 720
2	000348.jpg	720 x 720
3	000467.jpg	720 x 720
4	000607.jpg	720 x 720
5	000654.jpg	720 x 720
6	000740.jpg	720 x 720
7	000827.jpg	720 x 720
8	121-1-0.jpg	720 x 720
9	150-0-1.jpg	720 x 720
10	61-1-1.jpg	720 x 720
11	real-147.jpg	720 x 720
12	real-174.jpg	720 x 720
13	real-303.jpg	720 x 720
14	real-333.jpg	720 x 720
15	real-464.jpg	720 x 720
16	real-72.jpg	720 x 720

Source archive entries, SHA-256 fingerprints, mask hashes, actual missing fractions, run seeds, endpoint counts and automatic Canny thresholds are supplied in the accompanying machine-readable records. Image ownership and publication permissions require author verification; the numerical package does not grant additional rights over the source images.

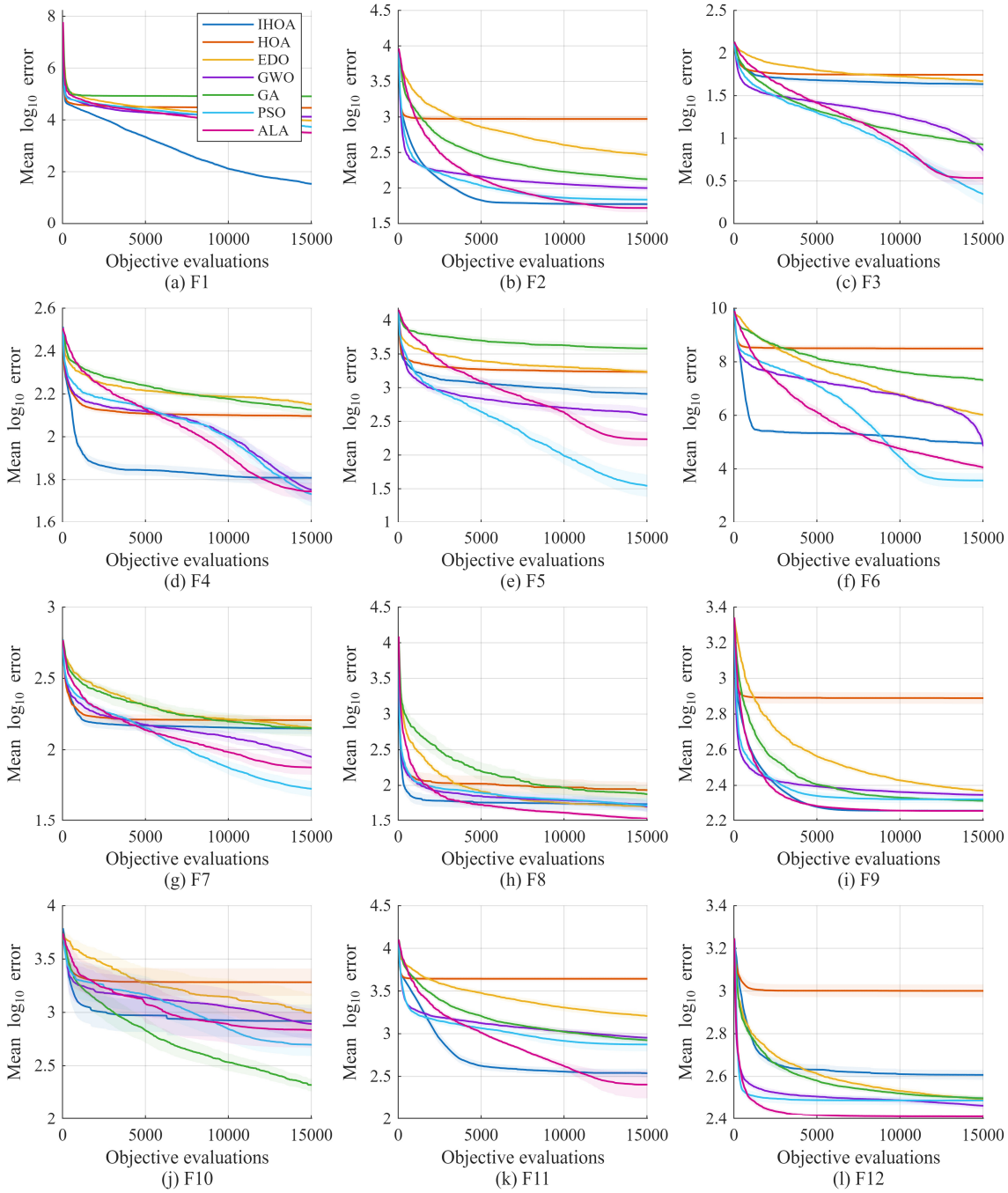


Figure S1. All-50-run convergence against objective evaluations. The ordinate is mean log10 error with a 10^-12 plotting floor; shading is a pointwise +/-1.96 standard-error interval, not a simultaneous confidence band. No favorable single run is selected.

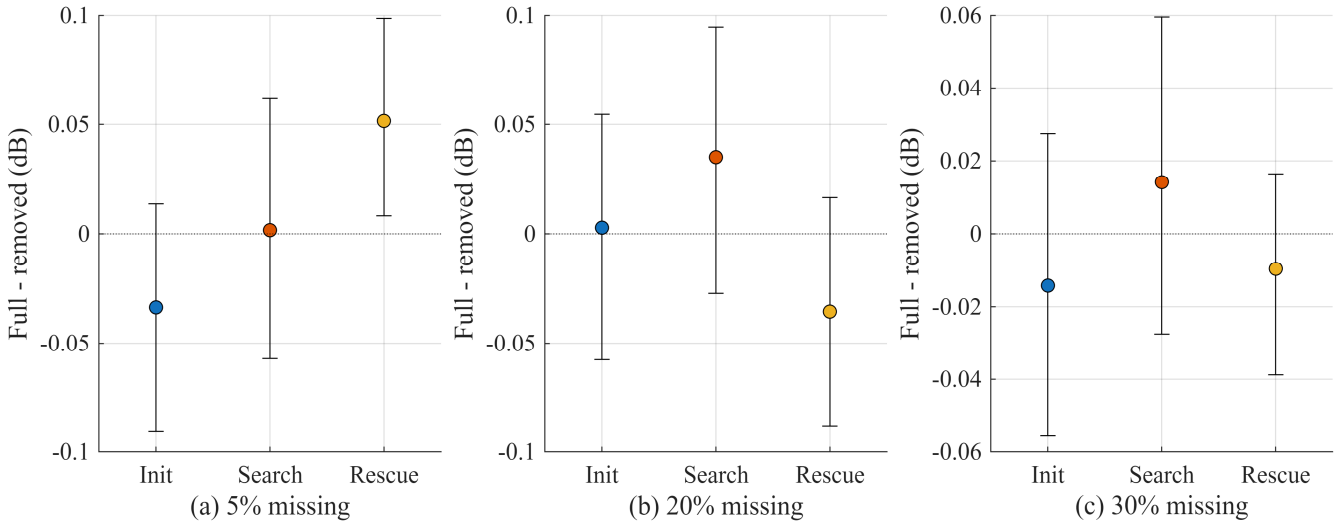
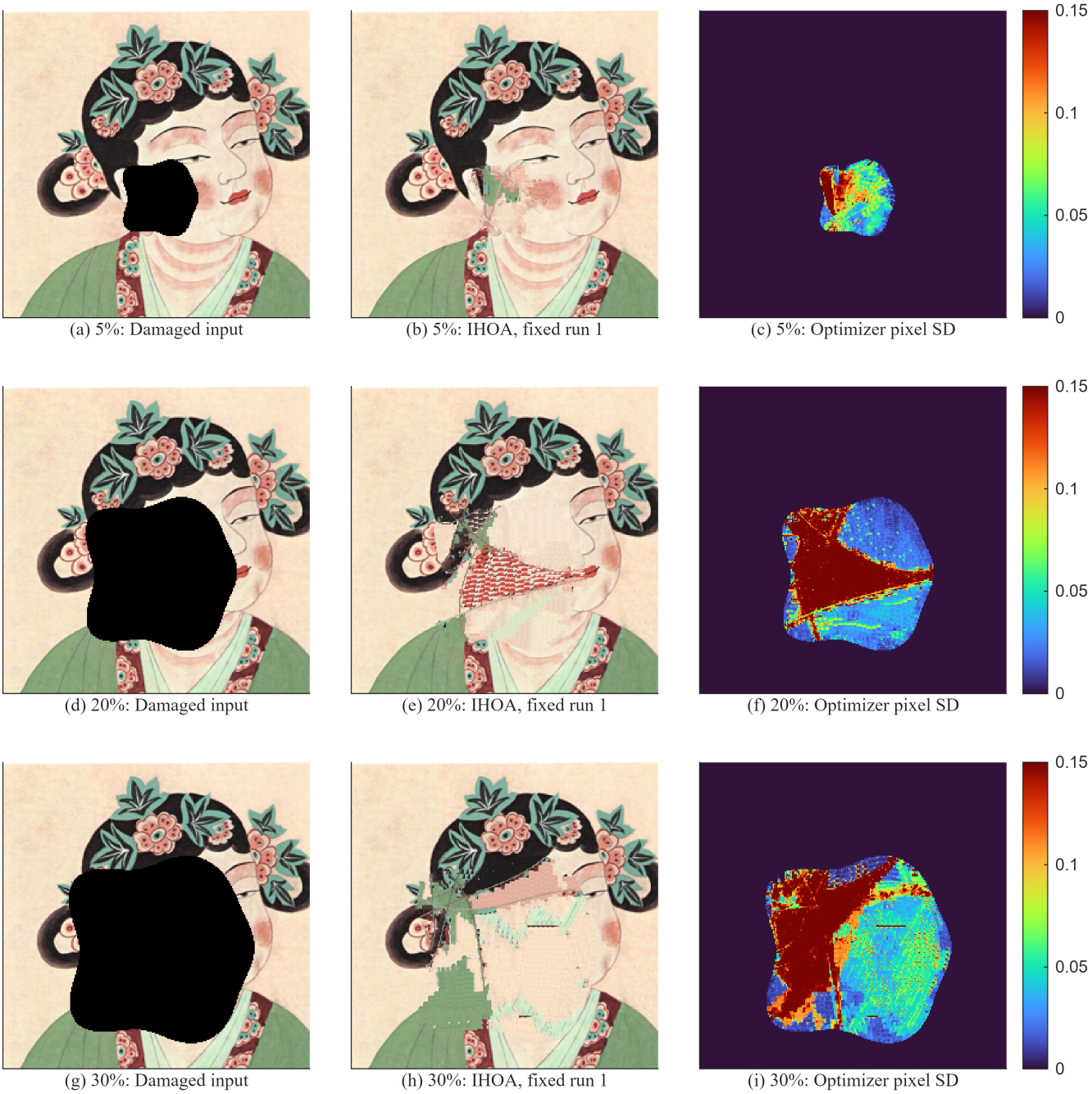


Figure S2. Paired restoration MaskPSNR changes after removal of each component. Points are full minus removed; bars are pointwise 95% image-level bootstrap intervals. Multiplicity-adjusted tests are reported separately in Table S4.



(a) 5%: Damaged input (b) 5%: IHOA, fixed run 1 (c) 5%: Optimizer pixel SD

(d) 20%: Damaged input (e) 20%: IHOA, fixed run 1 (f) 20%: Optimizer pixel SD

(g) 30%: Damaged input (h) 30%: IHOA, fixed run 1 (i) 30%: Optimizer pixel SD

Figure S3. Preselected image 1, mask 1: damaged input, fixed-run IHOA completion and across-run pixel standard deviation. Maps describe optimizer variability conditional on the model and mask, not historical authenticity or calibrated correctness. The raw numerical maps and binary generated-region masks are retained.

Table S11. Per-image PSNR and MaskPSNR of all seven algorithms at the three missing-area ratios.

For every image (case), algorithm, and missing-area ratio, the table reports the number of missing pixels, the actual fraction f of missing pixels in the mask, the full-image PSNR, the mask-restricted MaskPSNR, and their difference. Each image is downscaled with its aspect ratio preserved so that its longest side is 256 pixels; all sixteen selected images are square, so every case is evaluated at 256 × 256 pixels (65,536 pixels, 8-bit RGB, values scaled to [0,1]). The missing pixels are counted as integers, so the realized fraction f departs slightly from the nominal 5%, 20% and 30%. For the sixteen selected images, the resized images all contain 65,536 pixels. Each mask therefore contains the same number of pixels across images, and f is a property of the ratio rather than of the image. As implied by Eq. (27), the difference PSNR - MaskPSNR is the same for the seven algorithms at a given ratio and equals $10\log10(1/f)$ = 13.0100, 6.9898 and 5.2287 dB at the 5%, 20% and 30% ratios, respectively. The mean differences over the sixteen images, 13.0101, 6.9897 and 5.2288 dB, agree with these values to within 0.0001 dB, and the per-image differences agree to within 0.0002 dB, which is the rounding granularity of the four-decimal-point scores.

Known-pixel preservation: inside the restored images, the pixels outside the mask are identical to those of the reference image for all 336 restorations, since the restoration only writes into the masked region. MaskPSNR is obtained from the mean squared error restricted to the masked pixels on the same [0,1] dynamic range as the full-image PSNR. The sixteen per-image values of each column are averaged arithmetically, with the same mask used for all seven algorithms.

Image ID	Case	Missing pixels	Actual mask fraction f	Algorithm	PSNR (dB)	MaskPSNR (dB)	PSNR - MaskPSNR (dB)
(a) 5% missing ratio (f = 0.050003; 3277 missing pixels of 65,536)							
000098.jpg	1	3,277	0.050003	EDO	26.1144	13.1043	13.0101
000098.jpg	1	3,277	0.050003	GWO	26.5537	13.5436	13.0101
000098.jpg	1	3,277	0.050003	GA	26.1506	13.1405	13.0101
000098.jpg	1	3,277	0.050003	PSO	24.7740	11.7639	13.0101
000098.jpg	1	3,277	0.050003	ALA	26.7323	13.7222	13.0101
000098.jpg	1	3,277	0.050003	HOA	26.1333	13.1232	13.0101
000098.jpg	1	3,277	0.050003	IHOA	26.1810	13.1709	13.0101
000348.jpg	2	3,277	0.050003	EDO	25.5846	12.5745	13.0101
000348.jpg	2	3,277	0.050003	GWO	24.9224	11.9123	13.0101
000348.jpg	2	3,277	0.050003	GA	25.4327	12.4226	13.0101
000348.jpg	2	3,277	0.050003	PSO	25.6739	12.6638	13.0101
000348.jpg	2	3,277	0.050003	ALA	25.9655	12.9554	13.0101
000348.jpg	2	3,277	0.050003	HOA	25.1591	12.1490	13.0101
000348.jpg	2	3,277	0.050003	IHOA	25.9040	12.8939	13.0101
000467.jpg	3	3,277	0.050003	EDO	23.7695	10.7594	13.0101
000467.jpg	3	3,277	0.050003	GWO	22.8705	9.8604	13.0101
000467.jpg	3	3,277	0.050003	GA	24.0587	11.0486	13.0101
000467.jpg	3	3,277	0.050003	PSO	23.4303	10.4202	13.0101
000467.jpg	3	3,277	0.050003	ALA	23.1919	10.1818	13.0101
000467.jpg	3	3,277	0.050003	HOA	23.7367	10.7266	13.0101
000467.jpg	3	3,277	0.050003	IHOA	23.7541	10.7440	13.0101
000607.jpg	4	3,277	0.050003	EDO	23.1251	10.1150	13.0101
000607.jpg	4	3,277	0.050003	GWO	24.1731	11.1630	13.0101
000607.jpg	4	3,277	0.050003	GA	23.2583	10.2482	13.0101
000607.jpg	4	3,277	0.050003	PSO	23.0386	10.0285	13.0101
000607.jpg	4	3,277	0.050003	ALA	22.4847	9.4746	13.0101
000607.jpg	4	3,277	0.050003	HOA	22.6489	9.6388	13.0101
000607.jpg	4	3,277	0.050003	IHOA	23.5806	10.5705	13.0101
000654.jpg	5	3,277	0.050003	EDO	28.3807	15.3706	13.0101
000654.jpg	5	3,277	0.050003	GWO	28.4412	15.4311	13.0101
000654.jpg	5	3,277	0.050003	GA	27.5617	14.5516	13.0101
000654.jpg	5	3,277	0.050003	PSO	28.2149	15.2048	13.0101
000654.jpg	5	3,277	0.050003	ALA	28.0186	15.0085	13.0101
000654.jpg	5	3,277	0.050003	HOA	28.7094	15.6993	13.0101
000654.jpg	5	3,277	0.050003	IHOA	28.8013	15.7912	13.0101
000740.jpg	6	3,277	0.050003	EDO	28.1458	15.1357	13.0101
000740.jpg	6	3,277	0.050003	GWO	28.1288	15.1187	13.0101

000740.jpg	6	3,277	0.050003	GA	27.8228	14.8127	13.0101
000740.jpg	6	3,277	0.050003	PSO	28.3049	15.2948	13.0101
000740.jpg	6	3,277	0.050003	ALA	28.0322	15.0221	13.0101
000740.jpg	6	3,277	0.050003	HOA	28.7037	15.6936	13.0101
000740.jpg	6	3,277	0.050003	IHOA	28.1689	15.1588	13.0101
000827.jpg	7	3,277	0.050003	EDO	24.2065	11.1964	13.0101
000827.jpg	7	3,277	0.050003	GWO	23.8575	10.8474	13.0101
000827.jpg	7	3,277	0.050003	GA	24.2164	11.2063	13.0101
000827.jpg	7	3,277	0.050003	PSO	24.1399	11.1298	13.0101
000827.jpg	7	3,277	0.050003	ALA	24.1007	11.0906	13.0101
000827.jpg	7	3,277	0.050003	HOA	24.4061	11.3960	13.0101
000827.jpg	7	3,277	0.050003	IHOA	24.5192	11.5091	13.0101
121-1-0.jpg	8	3,277	0.050003	EDO	24.7224	11.7123	13.0101
121-1-0.jpg	8	3,277	0.050003	GWO	24.6201	11.6100	13.0101
121-1-0.jpg	8	3,277	0.050003	GA	24.4695	11.4594	13.0101
121-1-0.jpg	8	3,277	0.050003	PSO	23.9937	10.9836	13.0101
121-1-0.jpg	8	3,277	0.050003	ALA	24.5874	11.5773	13.0101
121-1-0.jpg	8	3,277	0.050003	HOA	24.2876	11.2775	13.0101
121-1-0.jpg	8	3,277	0.050003	IHOA	24.9190	11.9089	13.0101
150-0-1.jpg	9	3,277	0.050003	EDO	48.3212	35.3111	13.0101
150-0-1.jpg	9	3,277	0.050003	GWO	48.3212	35.3111	13.0101
150-0-1.jpg	9	3,277	0.050003	GA	48.3212	35.3111	13.0101
150-0-1.jpg	9	3,277	0.050003	PSO	48.3212	35.3111	13.0101
150-0-1.jpg	9	3,277	0.050003	ALA	48.3212	35.3111	13.0101
150-0-1.jpg	9	3,277	0.050003	HOA	48.3212	35.3111	13.0101
150-0-1.jpg	9	3,277	0.050003	IHOA	48.6212	35.6111	13.0101
61-1-1.jpg	10	3,277	0.050003	EDO	27.9478	14.9377	13.0101
61-1-1.jpg	10	3,277	0.050003	GWO	26.2128	13.2027	13.0101
61-1-1.jpg	10	3,277	0.050003	GA	26.5950	13.5849	13.0101
61-1-1.jpg	10	3,277	0.050003	PSO	26.4833	13.4732	13.0101
61-1-1.jpg	10	3,277	0.050003	ALA	27.2789	14.2688	13.0101
61-1-1.jpg	10	3,277	0.050003	HOA	26.4564	13.4463	13.0101
61-1-1.jpg	10	3,277	0.050003	IHOA	26.7034	13.6933	13.0101
real-147.jpg	11	3,277	0.050003	EDO	29.4430	16.4329	13.0101
real-147.jpg	11	3,277	0.050003	GWO	29.4648	16.4547	13.0101
real-147.jpg	11	3,277	0.050003	GA	29.2650	16.2549	13.0101
real-147.jpg	11	3,277	0.050003	PSO	29.0200	16.0099	13.0101
real-147.jpg	11	3,277	0.050003	ALA	29.0745	16.0644	13.0101
real-147.jpg	11	3,277	0.050003	HOA	28.7187	15.7086	13.0101
real-147.jpg	11	3,277	0.050003	IHOA	30.3254	17.3153	13.0101
real-174.jpg	12	3,277	0.050003	EDO	25.8813	12.8712	13.0101
real-174.jpg	12	3,277	0.050003	GWO	25.2969	12.2868	13.0101
real-174.jpg	12	3,277	0.050003	GA	25.3351	12.3250	13.0101
real-174.jpg	12	3,277	0.050003	PSO	25.9452	12.9351	13.0101
real-174.jpg	12	3,277	0.050003	ALA	25.6408	12.6307	13.0101
real-174.jpg	12	3,277	0.050003	HOA	26.2370	13.2269	13.0101
real-174.jpg	12	3,277	0.050003	IHOA	25.8089	12.7988	13.0101
real-303.jpg	13	3,277	0.050003	EDO	26.0678	13.0577	13.0101
real-303.jpg	13	3,277	0.050003	GWO	26.1501	13.1400	13.0101
real-303.jpg	13	3,277	0.050003	GA	26.2479	13.2378	13.0101
real-303.jpg	13	3,277	0.050003	PSO	25.9660	12.9559	13.0101
real-303.jpg	13	3,277	0.050003	ALA	25.6789	12.6688	13.0101
real-303.jpg	13	3,277	0.050003	HOA	25.7228	12.7127	13.0101
real-303.jpg	13	3,277	0.050003	IHOA	26.3798	13.3697	13.0101

real-333.jpg	14	3,277	0.050003	EDO	33.7794	20.7693	13.0101
real-333.jpg	14	3,277	0.050003	GWO	34.1423	21.1322	13.0101
real-333.jpg	14	3,277	0.050003	GA	32.6664	19.6563	13.0101
real-333.jpg	14	3,277	0.050003	PSO	33.3574	20.3473	13.0101
real-333.jpg	14	3,277	0.050003	ALA	33.2864	20.2763	13.0101
real-333.jpg	14	3,277	0.050003	HOA	33.3951	20.3850	13.0101
real-333.jpg	14	3,277	0.050003	IHOA	33.7347	20.7246	13.0101
real-464.jpg	15	3,277	0.050003	EDO	29.0884	16.0783	13.0101
real-464.jpg	15	3,277	0.050003	GWO	28.9407	15.9306	13.0101
real-464.jpg	15	3,277	0.050003	GA	29.2981	16.2880	13.0101
real-464.jpg	15	3,277	0.050003	PSO	29.8602	16.8501	13.0101
real-464.jpg	15	3,277	0.050003	ALA	30.1393	17.1292	13.0101
real-464.jpg	15	3,277	0.050003	HOA	29.1997	16.1896	13.0101
real-464.jpg	15	3,277	0.050003	IHOA	29.2882	16.2781	13.0101
real-72.jpg	16	3,277	0.050003	EDO	26.6434	13.6333	13.0101
real-72.jpg	16	3,277	0.050003	GWO	26.7211	13.7110	13.0101
real-72.jpg	16	3,277	0.050003	GA	26.5905	13.5804	13.0101
real-72.jpg	16	3,277	0.050003	PSO	26.3920	13.3819	13.0101
real-72.jpg	16	3,277	0.050003	ALA	25.8056	12.7955	13.0101
real-72.jpg	16	3,277	0.050003	HOA	26.3716	13.3615	13.0101
real-72.jpg	16	3,277	0.050003	IHOA	26.4576	13.4475	13.0101
(b) 20% missing ratio (f = 0.199997; 13107 missing pixels of 65,536)							
000098.jpg	1	13,107	0.199997	EDO	16.7349	9.7452	6.9897
000098.jpg	1	13,107	0.199997	GWO	14.4534	7.4637	6.9897
000098.jpg	1	13,107	0.199997	GA	16.0780	9.0883	6.9897
000098.jpg	1	13,107	0.199997	PSO	16.2170	9.2273	6.9897
000098.jpg	1	13,107	0.199997	ALA	15.0508	8.0611	6.9897
000098.jpg	1	13,107	0.199997	HOA	17.2304	10.2407	6.9897
000098.jpg	1	13,107	0.199997	IHOA	17.8745	10.8848	6.9897
000348.jpg	2	13,107	0.199997	EDO	18.5118	11.5221	6.9897
000348.jpg	2	13,107	0.199997	GWO	18.0791	11.0894	6.9897
000348.jpg	2	13,107	0.199997	GA	17.7919	10.8022	6.9897
000348.jpg	2	13,107	0.199997	PSO	18.3098	11.3201	6.9897
000348.jpg	2	13,107	0.199997	ALA	17.4934	10.5037	6.9897
000348.jpg	2	13,107	0.199997	HOA	18.2536	11.2639	6.9897
000348.jpg	2	13,107	0.199997	IHOA	18.0292	11.0395	6.9897
000467.jpg	3	13,107	0.199997	EDO	18.2538	11.2641	6.9897
000467.jpg	3	13,107	0.199997	GWO	17.9512	10.9615	6.9897
000467.jpg	3	13,107	0.199997	GA	18.3587	11.3690	6.9897
000467.jpg	3	13,107	0.199997	PSO	17.9468	10.9571	6.9897
000467.jpg	3	13,107	0.199997	ALA	17.6688	10.6791	6.9897
000467.jpg	3	13,107	0.199997	HOA	18.5390	11.5493	6.9897
000467.jpg	3	13,107	0.199997	IHOA	17.9512	10.9615	6.9897
000607.jpg	4	13,107	0.199997	EDO	17.4783	10.4886	6.9897
000607.jpg	4	13,107	0.199997	GWO	17.6824	10.6927	6.9897
000607.jpg	4	13,107	0.199997	GA	17.4878	10.4981	6.9897
000607.jpg	4	13,107	0.199997	PSO	17.6673	10.6776	6.9897
000607.jpg	4	13,107	0.199997	ALA	16.7802	9.7905	6.9897
000607.jpg	4	13,107	0.199997	HOA	16.4621	9.4724	6.9897
000607.jpg	4	13,107	0.199997	IHOA	17.1174	10.1277	6.9897
000654.jpg	5	13,107	0.199997	EDO	21.4730	14.4833	6.9897
000654.jpg	5	13,107	0.199997	GWO	21.9481	14.9584	6.9897
000654.jpg	5	13,107	0.199997	GA	22.1093	15.1196	6.9897
000654.jpg	5	13,107	0.199997	PSO	21.7334	14.7437	6.9897

000654.jpg	5	13,107	0.199997	ALA	21.6925	14.7028	6.9897
000654.jpg	5	13,107	0.199997	HOA	21.9984	15.0087	6.9897
000654.jpg	5	13,107	0.199997	IHOA	21.8623	14.8726	6.9897
000740.jpg	6	13,107	0.199997	EDO	21.1660	14.1763	6.9897
000740.jpg	6	13,107	0.199997	GWO	19.6237	12.6340	6.9897
000740.jpg	6	13,107	0.199997	GA	21.1107	14.1210	6.9897
000740.jpg	6	13,107	0.199997	PSO	19.7673	12.7776	6.9897
000740.jpg	6	13,107	0.199997	ALA	21.8247	14.8350	6.9897
000740.jpg	6	13,107	0.199997	HOA	21.1734	14.1837	6.9897
000740.jpg	6	13,107	0.199997	IHOA	20.7241	13.7344	6.9897
000827.jpg	7	13,107	0.199997	EDO	17.7969	10.8072	6.9897
000827.jpg	7	13,107	0.199997	GWO	18.2021	11.2124	6.9897
000827.jpg	7	13,107	0.199997	GA	17.7489	10.7592	6.9897
000827.jpg	7	13,107	0.199997	PSO	18.2912	11.3015	6.9897
000827.jpg	7	13,107	0.199997	ALA	18.1949	11.2052	6.9897
000827.jpg	7	13,107	0.199997	HOA	17.8822	10.8925	6.9897
000827.jpg	7	13,107	0.199997	IHOA	18.3313	11.3416	6.9897
121-1-0.jpg	8	13,107	0.199997	EDO	17.4507	10.4610	6.9897
121-1-0.jpg	8	13,107	0.199997	GWO	17.7778	10.7881	6.9897
121-1-0.jpg	8	13,107	0.199997	GA	18.0889	11.0992	6.9897
121-1-0.jpg	8	13,107	0.199997	PSO	17.8040	10.8143	6.9897
121-1-0.jpg	8	13,107	0.199997	ALA	17.9557	10.9660	6.9897
121-1-0.jpg	8	13,107	0.199997	HOA	17.0750	10.0853	6.9897
121-1-0.jpg	8	13,107	0.199997	IHOA	17.9687	10.9790	6.9897
150-0-1.jpg	9	13,107	0.199997	EDO	33.4064	26.4167	6.9897
150-0-1.jpg	9	13,107	0.199997	GWO	33.4023	26.4126	6.9897
150-0-1.jpg	9	13,107	0.199997	GA	33.3990	26.4093	6.9897
150-0-1.jpg	9	13,107	0.199997	PSO	33.4023	26.4126	6.9897
150-0-1.jpg	9	13,107	0.199997	ALA	33.4030	26.4133	6.9897
150-0-1.jpg	9	13,107	0.199997	HOA	33.4063	26.4166	6.9897
150-0-1.jpg	9	13,107	0.199997	IHOA	33.4030	26.4133	6.9897
61-1-1.jpg	10	13,107	0.199997	EDO	18.3246	11.3349	6.9897
61-1-1.jpg	10	13,107	0.199997	GWO	17.8982	10.9085	6.9897
61-1-1.jpg	10	13,107	0.199997	GA	18.0331	11.0434	6.9897
61-1-1.jpg	10	13,107	0.199997	PSO	17.6349	10.6452	6.9897
61-1-1.jpg	10	13,107	0.199997	ALA	17.7075	10.7178	6.9897
61-1-1.jpg	10	13,107	0.199997	HOA	17.7459	10.7562	6.9897
61-1-1.jpg	10	13,107	0.199997	IHOA	18.4718	11.4821	6.9897
real-147.jpg	11	13,107	0.199997	EDO	21.8294	14.8397	6.9897
real-147.jpg	11	13,107	0.199997	GWO	21.9134	14.9237	6.9897
real-147.jpg	11	13,107	0.199997	GA	21.5440	14.5543	6.9897
real-147.jpg	11	13,107	0.199997	PSO	21.8233	14.8336	6.9897
real-147.jpg	11	13,107	0.199997	ALA	21.8064	14.8167	6.9897
real-147.jpg	11	13,107	0.199997	HOA	21.9731	14.9834	6.9897
real-147.jpg	11	13,107	0.199997	IHOA	22.4089	15.4192	6.9897
real-174.jpg	12	13,107	0.199997	EDO	19.0200	12.0303	6.9897
real-174.jpg	12	13,107	0.199997	GWO	19.8028	12.8131	6.9897
real-174.jpg	12	13,107	0.199997	GA	19.3253	12.3356	6.9897
real-174.jpg	12	13,107	0.199997	PSO	19.6222	12.6325	6.9897
real-174.jpg	12	13,107	0.199997	ALA	18.9919	12.0022	6.9897
real-174.jpg	12	13,107	0.199997	HOA	18.6594	11.6697	6.9897
real-174.jpg	12	13,107	0.199997	IHOA	19.2081	12.2184	6.9897
real-303.jpg	13	13,107	0.199997	EDO	20.0742	13.0845	6.9897
real-303.jpg	13	13,107	0.199997	GWO	19.8524	12.8627	6.9897

real-303.jpg	13	13,107	0.199997	GA	19.2716	12.2819	6.9897
real-303.jpg	13	13,107	0.199997	PSO	19.5830	12.5933	6.9897
real-303.jpg	13	13,107	0.199997	ALA	19.5184	12.5287	6.9897
real-303.jpg	13	13,107	0.199997	HOA	20.0484	13.0587	6.9897
real-303.jpg	13	13,107	0.199997	IHOA	19.7076	12.7179	6.9897
real-333.jpg	14	13,107	0.199997	EDO	24.3746	17.3849	6.9897
real-333.jpg	14	13,107	0.199997	GWO	24.6537	17.6640	6.9897
real-333.jpg	14	13,107	0.199997	GA	25.0345	18.0448	6.9897
real-333.jpg	14	13,107	0.199997	PSO	23.0957	16.1060	6.9897
real-333.jpg	14	13,107	0.199997	ALA	24.0907	17.1010	6.9897
real-333.jpg	14	13,107	0.199997	HOA	24.8312	17.8415	6.9897
real-333.jpg	14	13,107	0.199997	IHOA	23.7039	16.7142	6.9897
real-464.jpg	15	13,107	0.199997	EDO	22.0632	15.0735	6.9897
real-464.jpg	15	13,107	0.199997	GWO	22.4738	15.4841	6.9897
real-464.jpg	15	13,107	0.199997	GA	21.8687	14.8790	6.9897
real-464.jpg	15	13,107	0.199997	PSO	22.1940	15.2043	6.9897
real-464.jpg	15	13,107	0.199997	ALA	22.3746	15.3849	6.9897
real-464.jpg	15	13,107	0.199997	HOA	20.1692	13.1795	6.9897
real-464.jpg	15	13,107	0.199997	IHOA	21.6078	14.6181	6.9897
real-72.jpg	16	13,107	0.199997	EDO	20.8040	13.8143	6.9897
real-72.jpg	16	13,107	0.199997	GWO	20.6542	13.6645	6.9897
real-72.jpg	16	13,107	0.199997	GA	20.9651	13.9754	6.9897
real-72.jpg	16	13,107	0.199997	PSO	20.5341	13.5444	6.9897
real-72.jpg	16	13,107	0.199997	ALA	20.8371	13.8474	6.9897
real-72.jpg	16	13,107	0.199997	HOA	20.4142	13.4245	6.9897
real-72.jpg	16	13,107	0.199997	IHOA	20.7486	13.7589	6.9897
		(c) 30% missing ratio (f = 0.300003; 19661 missing pixels of 65,536)					
000098.jpg	1	19,661	0.300003	EDO	15.5884	10.3596	5.2288
000098.jpg	1	19,661	0.300003	GWO	15.3514	10.1226	5.2288
000098.jpg	1	19,661	0.300003	GA	16.2237	10.9949	5.2288
000098.jpg	1	19,661	0.300003	PSO	13.2987	8.0699	5.2288
000098.jpg	1	19,661	0.300003	ALA	14.0763	8.8475	5.2288
000098.jpg	1	19,661	0.300003	HOA	12.8584	7.6296	5.2288
000098.jpg	1	19,661	0.300003	IHOA	14.7404	9.5116	5.2288
000348.jpg	2	19,661	0.300003	EDO	16.4281	11.1993	5.2288
000348.jpg	2	19,661	0.300003	GWO	16.6238	11.3950	5.2288
000348.jpg	2	19,661	0.300003	GA	16.4228	11.1940	5.2288
000348.jpg	2	19,661	0.300003	PSO	15.3208	10.0920	5.2288
000348.jpg	2	19,661	0.300003	ALA	16.5398	11.3110	5.2288
000348.jpg	2	19,661	0.300003	HOA	16.6439	11.4151	5.2288
000348.jpg	2	19,661	0.300003	IHOA	16.5415	11.3127	5.2288
000467.jpg	3	19,661	0.300003	EDO	16.9278	11.6990	5.2288
000467.jpg	3	19,661	0.300003	GWO	16.6053	11.3765	5.2288
000467.jpg	3	19,661	0.300003	GA	16.8585	11.6297	5.2288
000467.jpg	3	19,661	0.300003	PSO	16.9491	11.7203	5.2288
000467.jpg	3	19,661	0.300003	ALA	16.8828	11.6540	5.2288
000467.jpg	3	19,661	0.300003	HOA	16.3222	11.0934	5.2288
000467.jpg	3	19,661	0.300003	IHOA	16.5364	11.3076	5.2288
000607.jpg	4	19,661	0.300003	EDO	14.9817	9.7529	5.2288
000607.jpg	4	19,661	0.300003	GWO	15.5558	10.3270	5.2288
000607.jpg	4	19,661	0.300003	GA	15.8672	10.6384	5.2288
000607.jpg	4	19,661	0.300003	PSO	15.6074	10.3786	5.2288
000607.jpg	4	19,661	0.300003	ALA	15.1593	9.9305	5.2288
000607.jpg	4	19,661	0.300003	HOA	15.0432	9.8144	5.2288

000607.jpg	4	19,661	0.300003	IHOA	15.6751	10.4463	5.2288
000654.jpg	5	19,661	0.300003	EDO	18.8988	13.6700	5.2288
000654.jpg	5	19,661	0.300003	GWO	19.2100	13.9812	5.2288
000654.jpg	5	19,661	0.300003	GA	19.1787	13.9499	5.2288
000654.jpg	5	19,661	0.300003	PSO	19.4250	14.1962	5.2288
000654.jpg	5	19,661	0.300003	ALA	19.1194	13.8906	5.2288
000654.jpg	5	19,661	0.300003	HOA	18.6650	13.4362	5.2288
000654.jpg	5	19,661	0.300003	IHOA	19.4302	14.2014	5.2288
000740.jpg	6	19,661	0.300003	EDO	18.2742	13.0454	5.2288
000740.jpg	6	19,661	0.300003	GWO	18.1620	12.9332	5.2288
000740.jpg	6	19,661	0.300003	GA	18.5551	13.3263	5.2288
000740.jpg	6	19,661	0.300003	PSO	18.9029	13.6741	5.2288
000740.jpg	6	19,661	0.300003	ALA	18.6235	13.3947	5.2288
000740.jpg	6	19,661	0.300003	HOA	18.2259	12.9971	5.2288
000740.jpg	6	19,661	0.300003	IHOA	18.2778	13.0490	5.2288
000827.jpg	7	19,661	0.300003	EDO	16.3489	11.1201	5.2288
000827.jpg	7	19,661	0.300003	GWO	16.2527	11.0239	5.2288
000827.jpg	7	19,661	0.300003	GA	16.2900	11.0612	5.2288
000827.jpg	7	19,661	0.300003	PSO	16.3350	11.1062	5.2288
000827.jpg	7	19,661	0.300003	ALA	16.5596	11.3308	5.2288
000827.jpg	7	19,661	0.300003	HOA	16.3021	11.0733	5.2288
000827.jpg	7	19,661	0.300003	IHOA	16.7202	11.4914	5.2288
121-1-0.jpg	8	19,661	0.300003	EDO	15.7509	10.5221	5.2288
121-1-0.jpg	8	19,661	0.300003	GWO	15.7768	10.5480	5.2288
121-1-0.jpg	8	19,661	0.300003	GA	16.3189	11.0901	5.2288
121-1-0.jpg	8	19,661	0.300003	PSO	15.9925	10.7637	5.2288
121-1-0.jpg	8	19,661	0.300003	ALA	15.5376	10.3088	5.2288
121-1-0.jpg	8	19,661	0.300003	HOA	16.3329	11.1041	5.2288
121-1-0.jpg	8	19,661	0.300003	IHOA	15.9756	10.7468	5.2288
150-0-1.jpg	9	19,661	0.300003	EDO	22.4434	17.2146	5.2288
150-0-1.jpg	9	19,661	0.300003	GWO	23.6314	18.4026	5.2288
150-0-1.jpg	9	19,661	0.300003	GA	21.2150	15.9862	5.2288
150-0-1.jpg	9	19,661	0.300003	PSO	24.3116	19.0828	5.2288
150-0-1.jpg	9	19,661	0.300003	ALA	23.5312	18.3024	5.2288
150-0-1.jpg	9	19,661	0.300003	HOA	23.2286	17.9998	5.2288
150-0-1.jpg	9	19,661	0.300003	IHOA	24.9364	19.7076	5.2288
61-1-1.jpg	10	19,661	0.300003	EDO	16.3165	11.0877	5.2288
61-1-1.jpg	10	19,661	0.300003	GWO	16.6464	11.4176	5.2288
61-1-1.jpg	10	19,661	0.300003	GA	16.7575	11.5287	5.2288
61-1-1.jpg	10	19,661	0.300003	PSO	16.5577	11.3289	5.2288
61-1-1.jpg	10	19,661	0.300003	ALA	16.8961	11.6673	5.2288
61-1-1.jpg	10	19,661	0.300003	HOA	16.6665	11.4377	5.2288
61-1-1.jpg	10	19,661	0.300003	IHOA	16.4577	11.2289	5.2288
real-147.jpg	11	19,661	0.300003	EDO	21.2210	15.9922	5.2288
real-147.jpg	11	19,661	0.300003	GWO	20.7237	15.4949	5.2288
real-147.jpg	11	19,661	0.300003	GA	20.3905	15.1617	5.2288
real-147.jpg	11	19,661	0.300003	PSO	21.7699	16.5411	5.2288
real-147.jpg	11	19,661	0.300003	ALA	20.9543	15.7255	5.2288
real-147.jpg	11	19,661	0.300003	HOA	20.5354	15.3066	5.2288
real-147.jpg	11	19,661	0.300003	IHOA	21.0357	15.8069	5.2288
real-174.jpg	12	19,661	0.300003	EDO	17.0896	11.8608	5.2288
real-174.jpg	12	19,661	0.300003	GWO	17.0379	11.8091	5.2288
real-174.jpg	12	19,661	0.300003	GA	17.9232	12.6944	5.2288
real-174.jpg	12	19,661	0.300003	PSO	17.9389	12.7101	5.2288

real-174.jpg	12	19,661	0.300003	ALA	18.4684	13.2396	5.2288
real-174.jpg	12	19,661	0.300003	HOA	17.4177	12.1889	5.2288
real-174.jpg	12	19,661	0.300003	IHOA	18.4093	13.1805	5.2288
real-303.jpg	13	19,661	0.300003	EDO	17.6009	12.3721	5.2288
real-303.jpg	13	19,661	0.300003	GWO	18.5252	13.2964	5.2288
real-303.jpg	13	19,661	0.300003	GA	18.0676	12.8388	5.2288
real-303.jpg	13	19,661	0.300003	PSO	17.8404	12.6116	5.2288
real-303.jpg	13	19,661	0.300003	ALA	18.5366	13.3078	5.2288
real-303.jpg	13	19,661	0.300003	HOA	18.4792	13.2504	5.2288
real-303.jpg	13	19,661	0.300003	IHOA	18.1439	12.9151	5.2288
real-333.jpg	14	19,661	0.300003	EDO	21.8907	16.6619	5.2288
real-333.jpg	14	19,661	0.300003	GWO	23.0826	17.8538	5.2288
real-333.jpg	14	19,661	0.300003	GA	18.9373	13.7085	5.2288
real-333.jpg	14	19,661	0.300003	PSO	21.1926	15.9638	5.2288
real-333.jpg	14	19,661	0.300003	ALA	21.0242	15.7954	5.2288
real-333.jpg	14	19,661	0.300003	HOA	22.1403	16.9115	5.2288
real-333.jpg	14	19,661	0.300003	IHOA	21.7566	16.5278	5.2288
real-464.jpg	15	19,661	0.300003	EDO	20.8368	15.6080	5.2288
real-464.jpg	15	19,661	0.300003	GWO	20.5518	15.3230	5.2288
real-464.jpg	15	19,661	0.300003	GA	19.3378	14.1090	5.2288
real-464.jpg	15	19,661	0.300003	PSO	20.0563	14.8275	5.2288
real-464.jpg	15	19,661	0.300003	ALA	19.3320	14.1032	5.2288
real-464.jpg	15	19,661	0.300003	HOA	20.7746	15.5458	5.2288
real-464.jpg	15	19,661	0.300003	IHOA	20.7261	15.4973	5.2288
real-72.jpg	16	19,661	0.300003	EDO	18.6767	13.4479	5.2288
real-72.jpg	16	19,661	0.300003	GWO	18.5962	13.3674	5.2288
real-72.jpg	16	19,661	0.300003	GA	18.6976	13.4688	5.2288
real-72.jpg	16	19,661	0.300003	PSO	18.7783	13.5495	5.2288
real-72.jpg	16	19,661	0.300003	ALA	18.3863	13.1575	5.2288
real-72.jpg	16	19,661	0.300003	HOA	18.7716	13.5428	5.2288
real-72.jpg	16	19,661	0.300003	IHOA	18.9315	13.7027	5.2288

Table S12. Arithmetical means of Table S11 over the sixteen images.

The mean difference column is the average of PSNR - MaskPSNR over the sixteen images and is identical for the seven algorithms at a given ratio.

Ratio	f	Algorithm	Mean PSNR (dB)	Mean MaskPSNR (dB)	Mean difference (dB)
5%	0.050003	EDO	28.2013	15.1912	13.0101
5%	0.050003	GWO	28.0511	15.0410	13.0101
5%	0.050003	GA	27.9556	14.9455	13.0101
5%	0.050003	PSO	27.9322	14.9221	13.0101
5%	0.050003	ALA	28.0212	15.0111	13.0101
5%	0.050003	HOA	28.0130	15.0029	13.0101
5%	**0.050003**	**IHOA**	**28.3217**	**15.3116**	**13.0101**
20%	0.199997	EDO	20.5476	13.5579	6.9897
20%	0.199997	GWO	20.3980	13.4083	6.9897
20%	0.199997	GA	20.5135	13.5238	6.9897
20%	0.199997	PSO	20.3516	13.3619	6.9897
20%	0.199997	ALA	20.3369	13.3472	6.9897
20%	0.199997	HOA	20.3664	13.3767	6.9897
20%	**0.199997**	**IHOA**	**20.5699**	**13.5802**	**6.9897**
30%	0.300003	EDO	18.0797	12.8508	5.2288
30%	0.300003	GWO	18.2708	13.0420	5.2288
30%	0.300003	GA	17.9401	12.7113	5.2288
30%	0.300003	PSO	18.1423	12.9135	5.2288
30%	0.300003	ALA	18.1017	12.8729	5.2288

30%	0.300003	HOA	18.0255	12.7967	5.2288
30%	**0.300003**	**IHOA**	**18.3934**	**13.1646**	**5.2288**