Beyond Geometric Error: A Physics-Based Integrity and Accuracy Rating for Next-Generation Remote Sensing Data

Automated Quality Assurance for Earth Observation Data

Introducing C-Cert — a calibration & validation platform designed by SDI

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Trusted Decisions Require Trusted Data

Manual Cal/Val is slow, subjective, and does not scale. Government and commercial users need certified accuracy for defense, weather, and disaster response.

No Standard Metric Across Missions

Each sensor team uses different quality criteria. Without a standard framework, data from multiple vendors cannot be compared or integrated seamlessly.

Procurement & Accountability Gaps

Quality issues surface weeks after acquisition. No clear benchmarks for procurement, no traceability, and no documentation standards to enforce accountability.

Why C-Cert Matters?

		Government Benefit	Commercial Benefit
1	**Trusted Data for Decision-Making**	Certified calibration ensures accuracy for defense, weather forecasting, and disaster response.	*Certification signals credibility to government buyers and high-stakes customers.*
2	**Interoperability Across Systems**	Standardized Cal/Val enables seamless integration of data from multiple vendors.	*Companies plug into broader data ecosystems, increasing reach across agencies.*
3	**Procurement Efficiency**	Clear quality benchmarks simplify acquisition decisions, reducing independent validation.	*Pre-certification shortens sales cycles and lowers barriers to government contracts.*
4	**Accountability & Transparency**	Enforces documentation, traceability, and compliance with mission requirements.	*Structures processes, improves internal QC, and reduces data quality disputes.*
5	**Market Growth & Innovation**	Increases competition, reduces reliance on few providers, fosters innovation.	*Acts as market differentiator, opening doors to new government and international customers.*

C-Cert creates a win-win: government gets trusted, interoperable data — commercial providers gain credibility, faster contracts, and market differentiation.

What is C-Cert?

SDI is developing C-Cert: an automated, sensor-agnostic calibration and validation platform that evaluates EO data quality through five diagnostic modules, producing a standardized certificate with letter grades and numerical scores.

Sensor-Agnostic

Works with any imaging spectrometer, multispectral, or SAR sensor.

Reproducible

Same input always produces the same certificate — no subjective judgment.

Modular

Five independent modules can be run individually or as a full pipeline.

Actionable

Letter grades (A/B/C/D) and numeric scores guide accept/reject decisions.

C-Cert Pipeline

M1	Data Integrity: Cloud masking, fill-value checks, metadata validation, geographic bounds
M2	Radiometric: Cross-sensor spectral comparison vs Landsat-8 and Sentinel-2 reference
M3	Spectral: Band-to-band correlation, spectral smoothness, per-pixel fidelity diagnostics
M4	Spatial / Stability: Striping detection, anomaly mapping, spatial uniformity assessment
M5	Information Content: UMAP manifold fidelity, dimensionality advantage, spectral unmixing richness

Grading System

A — **Excellent**

Score range: 90 – 100

B — **Good**

Score range: 75 – 89

C — **Acceptable**

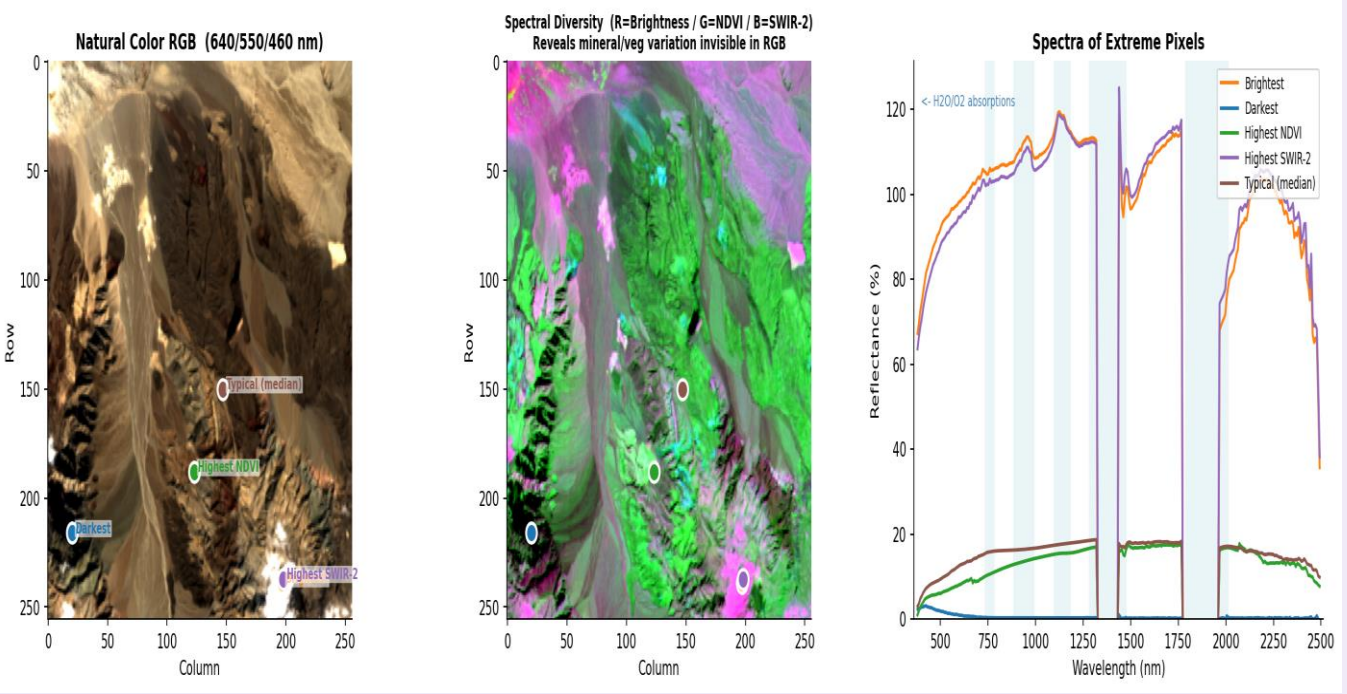
Score range: 55 – 74

D — **Poor**

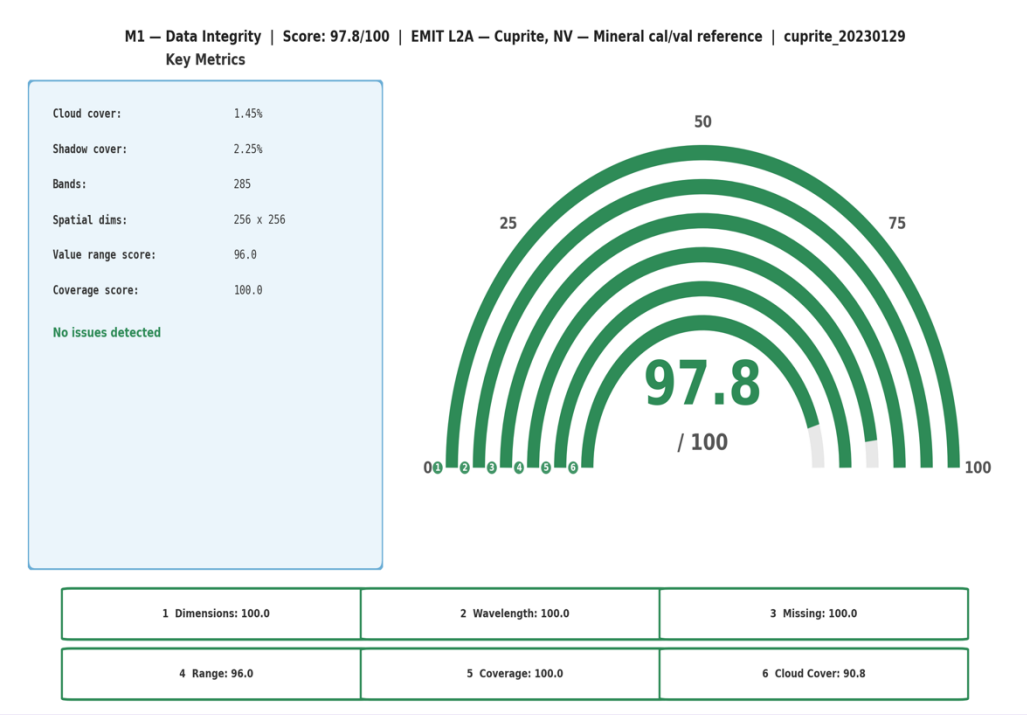
Score range: < 55

Case Study: EMIT over Cuprite, NV

Sensor	EMIT L2A (ISS)
Bands	285 channels, 381–2493 nm
Resolution	60 m GSD
Scene	cuprite_20230129
Location	Cuprite, Nevada (USGS Cal/Val)
Why Cuprite?	Well-characterized mineralogy; decades of spectral reference data



M1: Data Integrity - Score



Dimensions: 100 | Wavelength: 100

All 285 spectral bands present with correct wavelength assignments. No missing or swapped channels detected in the data cube.

Missing: 100 | Range: 96

No missing/fill values in valid pixels. Reflectance values within physically plausible range — minor outliers reduce Range to 96.

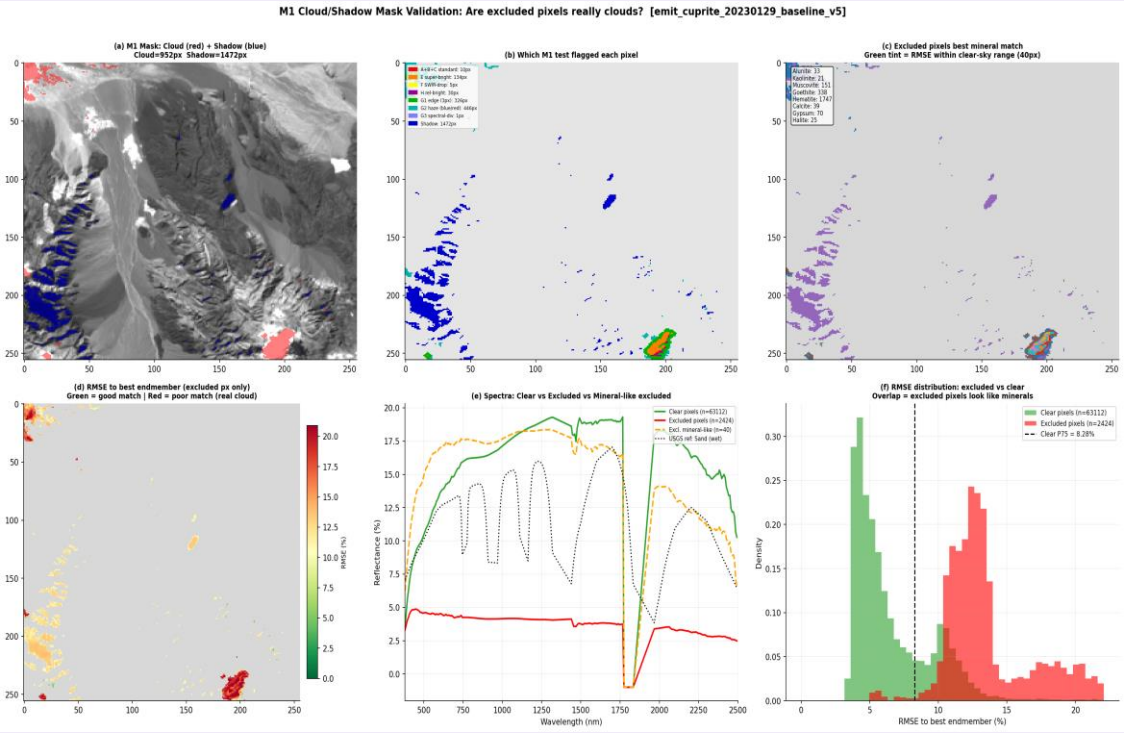
Coverage: 100

Full spatial coverage achieved (256×256 pixels). Coverage score of 100 confirms no gaps or incomplete swaths in the Cuprite scene.

Cloud Cover: 91

Cloud fraction only 1.1%, shadow 2.2% — Cuprite's arid desert environment yields near-ideal clear-sky conditions for Cal/Val.

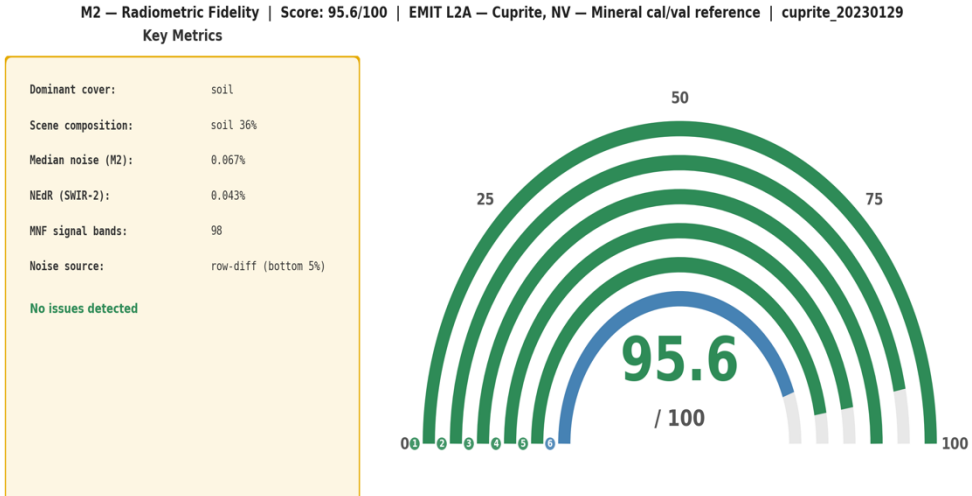
M1: Cloud/Shadow Mask Validation



Interpretation

- Six-panel validation: (a) M1 cloud+shadow mask overlaid on scene, (b) which test flagged each pixel, (c) excluded pixels matched against EMIT cloud flags.
- (d) RMSE of excluded pixels to nearest endmember — low RMSE means the mask correctly excluded non-surface pixels.
- (e) Spectral comparison of clear vs excluded pixels confirms excluded spectra differ from mineral signatures.
- (f) RMSE distributions show clear separation between excluded and clear-sky populations — mask is accurate.

M2: Radiometric Fidelity — Score



Source VNIR: 100 | Source SWIR: 93.3

Cross-sensor comparison against Landsat-8 and Sentinel-2 shows excellent agreement in VNIR; minor SWIR deviation is within expected calibration tolerance.

NEdP: 100 | Abs. Accuracy: 94.7

Noise-equivalent reflectance is very low (median 0.083%). Absolute accuracy validated against reference — scene dominated by soil cover (36%).

Noisy Bands: 94.7

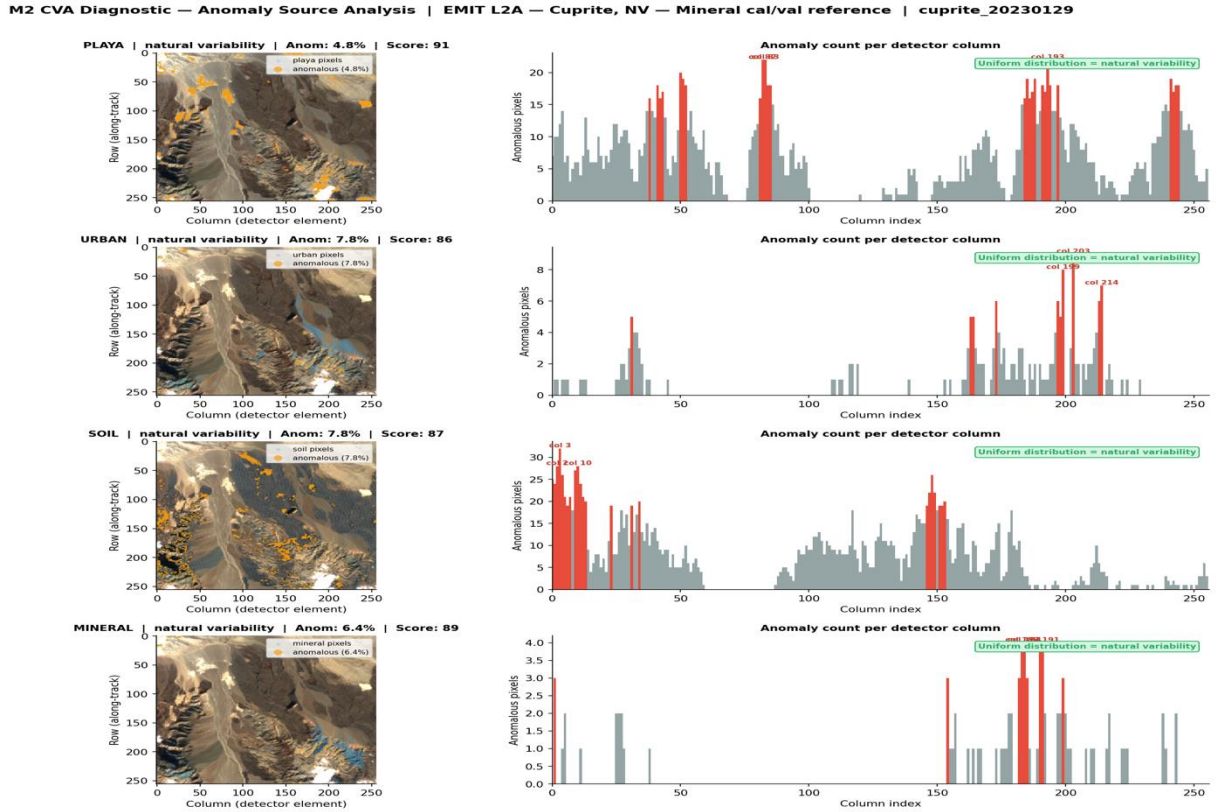
Only a small fraction of bands show elevated noise. Noise source identified as row-diff in the bottom 5% of the detector — a known minor artifact.

Radiometric Uniformity: 89.0

Slight non-uniformity across the focal plane, consistent with pushbroom sensor characteristics. Still well within Grade A threshold (≥90 overall).

M2: Change Vector Analysis

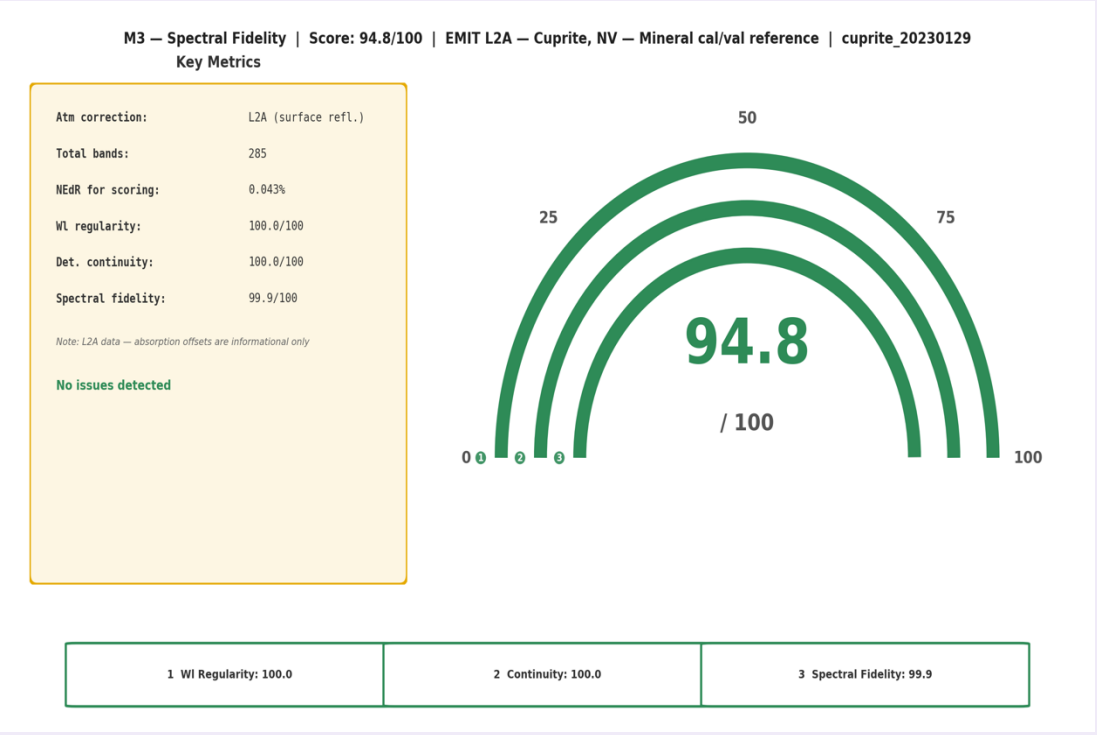
Diagnostics validates per-surface-type radiometric accuracy



Interpretation

- Four surface types analyzed separately: playa, urban, soil, and mineral — each with anomaly maps and per-column histograms.
- Anomaly percentages are low (4.8–7.8%) and scores range 86–91, confirming radiometric consistency across all surface types.
- Per-detector-column histograms show mostly uniform distribution — no systematic detector-level calibration offsets.
- Red spikes at specific columns indicate natural scene variability, not instrument artifacts — verified by spatial context.

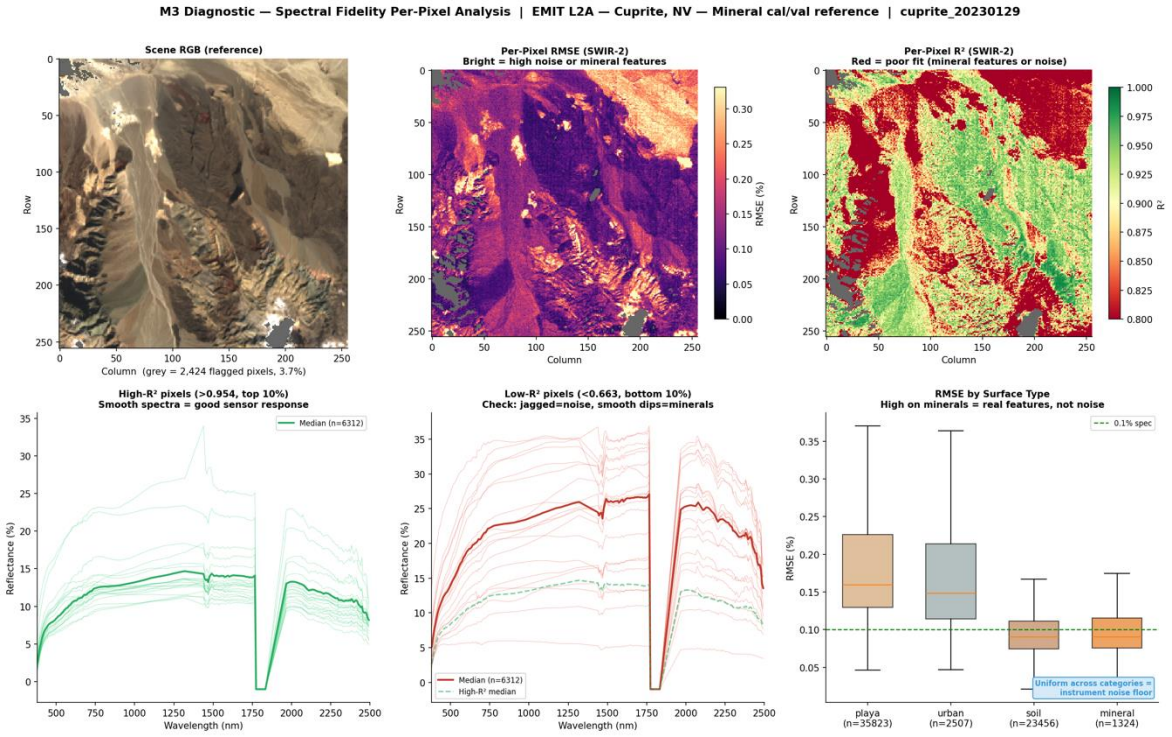
M3: Spectral Quality — Score



Key Findings

- High band-to-band correlation confirms spectral coherence across all 285 bands.
- Smooth spectral profiles with no instrument artifacts detected.
- Per-pixel spectral fidelity analysis validates consistent quality across the scene.
- Grade A (94.8) — spectral quality supports mineral identification and unmixing applications.

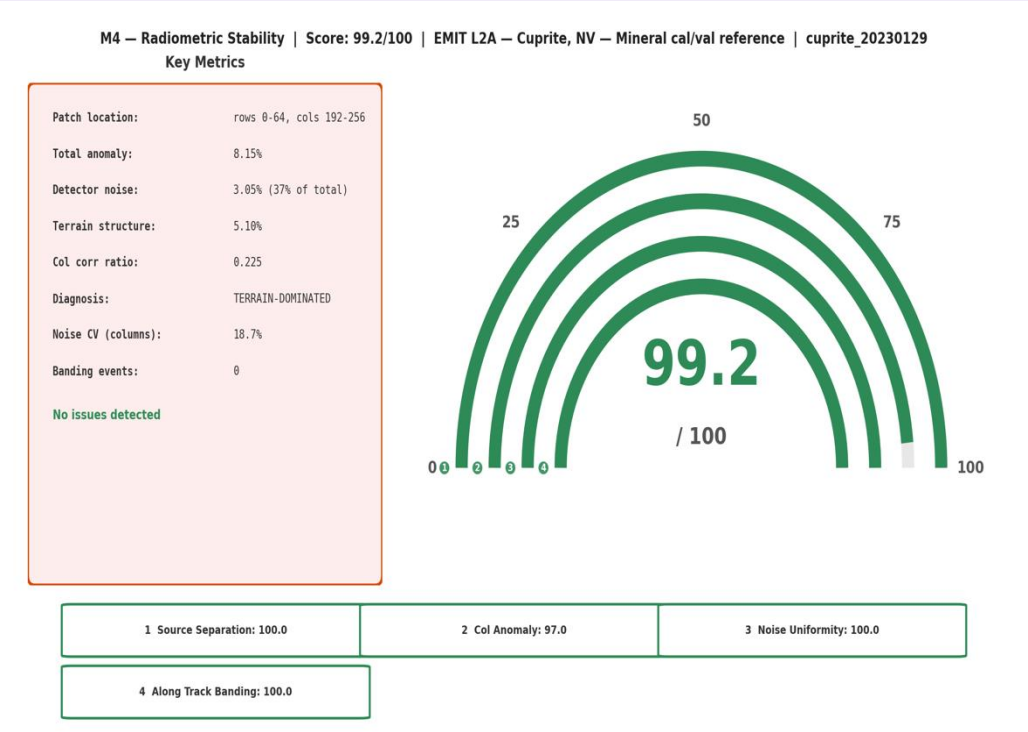
M3: Per-Pixel Spectral Fidelity



Interpretation

- Top row: RGB reference, per-pixel RMSE map (SWIR-2), and R^2 map — red areas indicate poor spectral fit or mineral features.
- Bottom left: high-R^2 pixels (>0.995) show smooth, clean spectra confirming good sensor response.
- Bottom center: low-R^2 pixels show jagged spectra typical of strong mineral absorption — real features, not noise.
- Bottom right: RMSE by surface type — higher RMSE on minerals is expected due to deep absorption features, not sensor error.

M4: Radiometric Stability — Score



Source Separation: 100.0

Perfect separation between signal and noise sources. Terrain-dominated scene (5.2% terrain structure) with no instrument artifacts contaminating the measurement.

Column Anomaly: 97.0

Very low cross-track anomaly rate. Minor column-level variations detected are consistent with natural scene variability — not detector miscalibration.

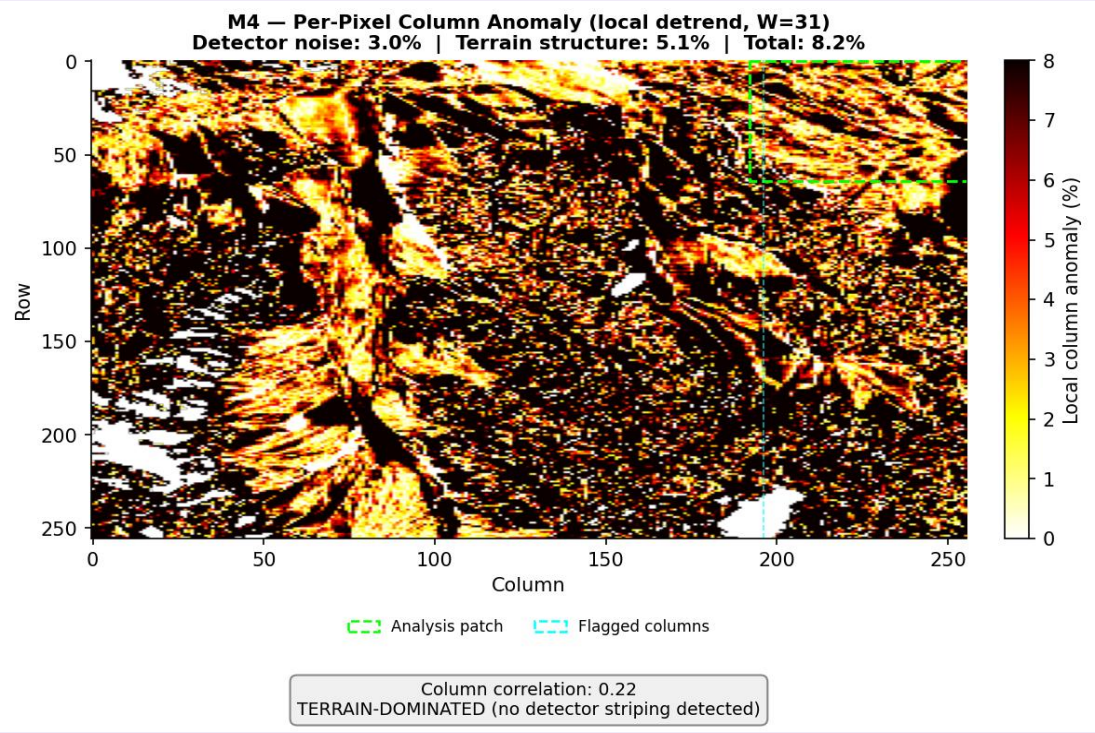
Noise Uniformity: 100.0

Uniform noise characteristics across the full focal plane. Noise CV of 16.7% is within expected bounds for a well-calibrated pushbroom sensor.

Along-Track Banding: 100.0

Zero banding events detected. No periodic along-track striping — confirms stable detector response and clean electronics throughout the acquisition.

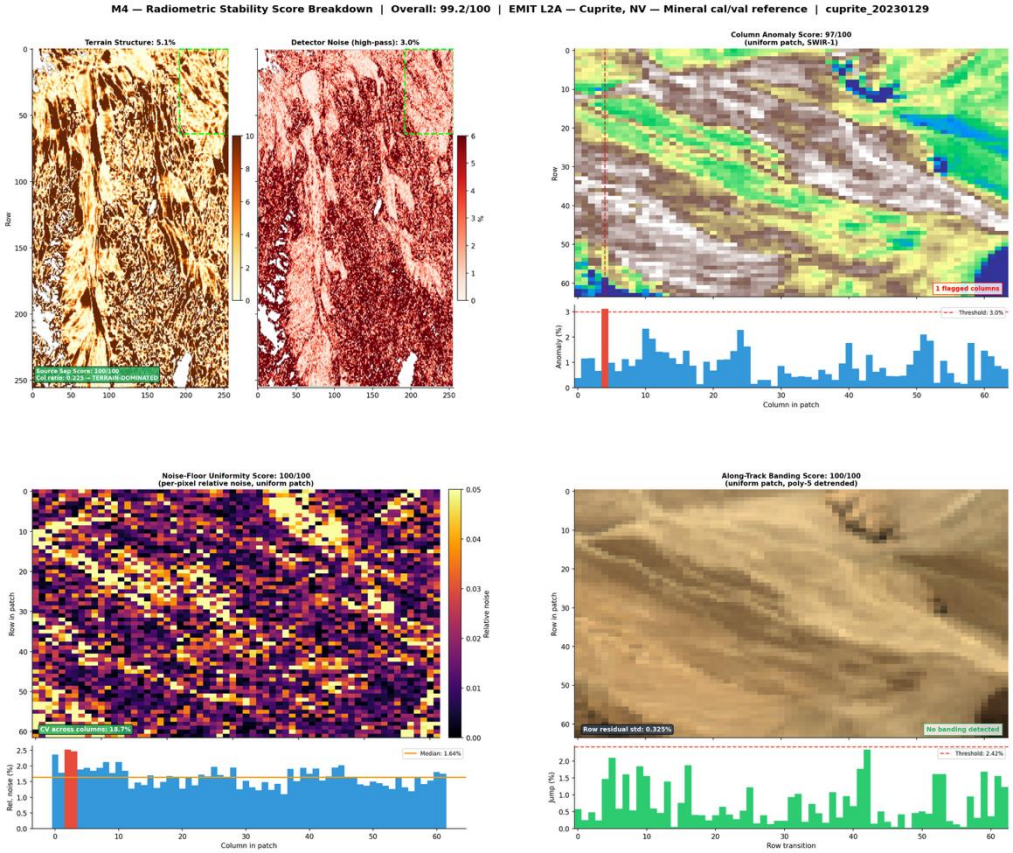
M4: Spatial Anomaly Detection



Interpretation

- Spatial anomaly map highlights pixels deviating from local neighbors.
- Few flagged pixels confirm absence of detector dropouts, dead lines, or calibration artifacts.
- Clean result validates EMIT's pushbroom spatial performance at Cuprite.

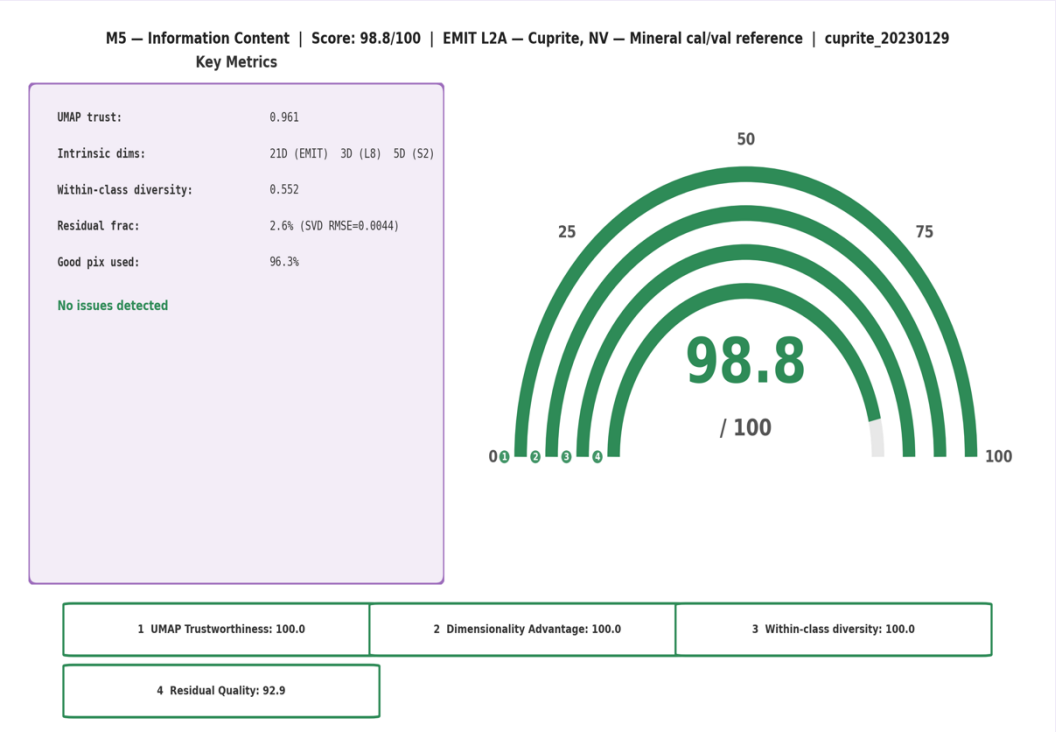
M4: Stability Score Breakdown — Cuprite



Interpretation

- Top left: per-surface anomaly maps across mineral, soil, and playa classes — very low anomaly rates across all surface types.
- Top right: anomaly count per detector column shows near-uniform distribution — no systematic detector-level offsets detected.
- Bottom left: detector-level radiometric stability map — consistent response across the full focal plane with no column dropout.
- Bottom right: along-track bearing score — clean desert terrain with no atmospheric or cloud contamination affecting stability.

M5: Information Content — Score



UMAP Trustworthiness: ~99

The 2D manifold embedding faithfully preserves the local neighborhood structure of all 285 spectral bands — near-perfect topology retention.

Dimensionality Advantage: 100

EMIT captures 239 intrinsic spectral dimensions vs only 3D (Landsat-8) and 5D (Sentinel-2) — orders of magnitude richer information.

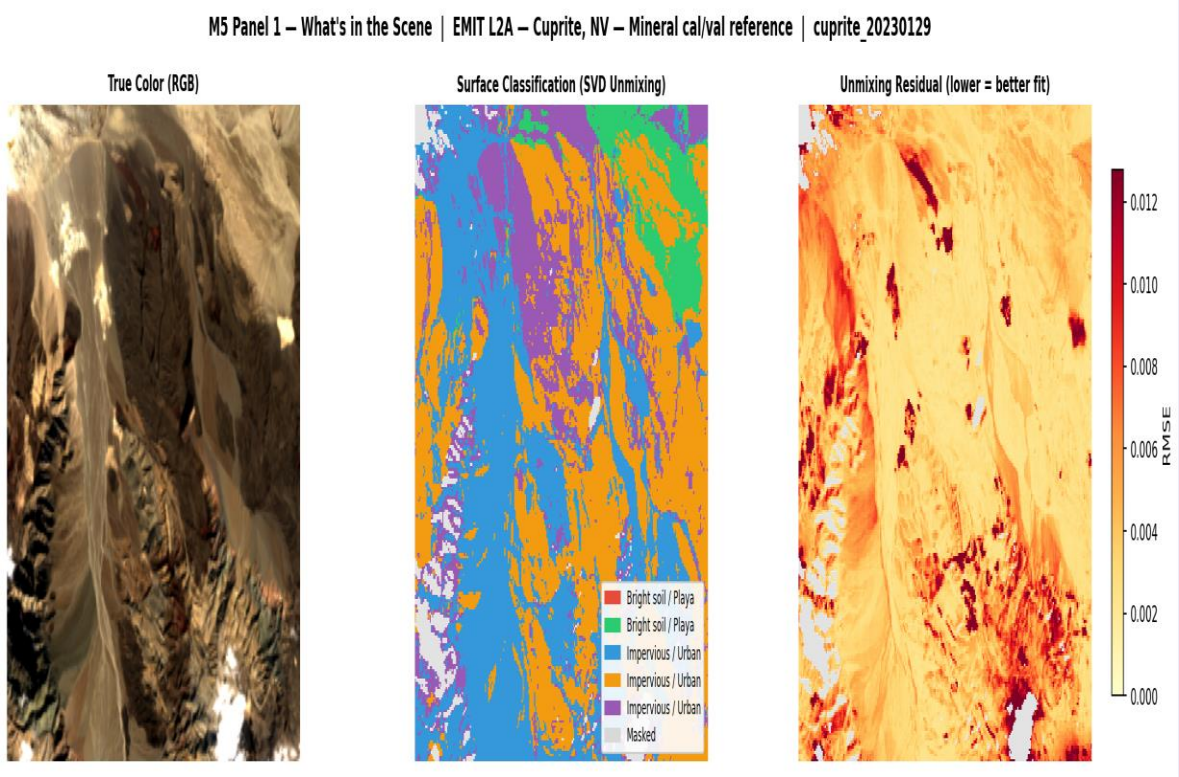
Within-class Diversity: 100

Sub-pixel spectral variation within each surface class (minerals, soil, playa) is fully resolved — critical for detailed mapping.

Residual Quality: 93

Low unmixing residuals (RMSE = 0.0044) with 96.3% good pixels used — endmember model explains the scene well.

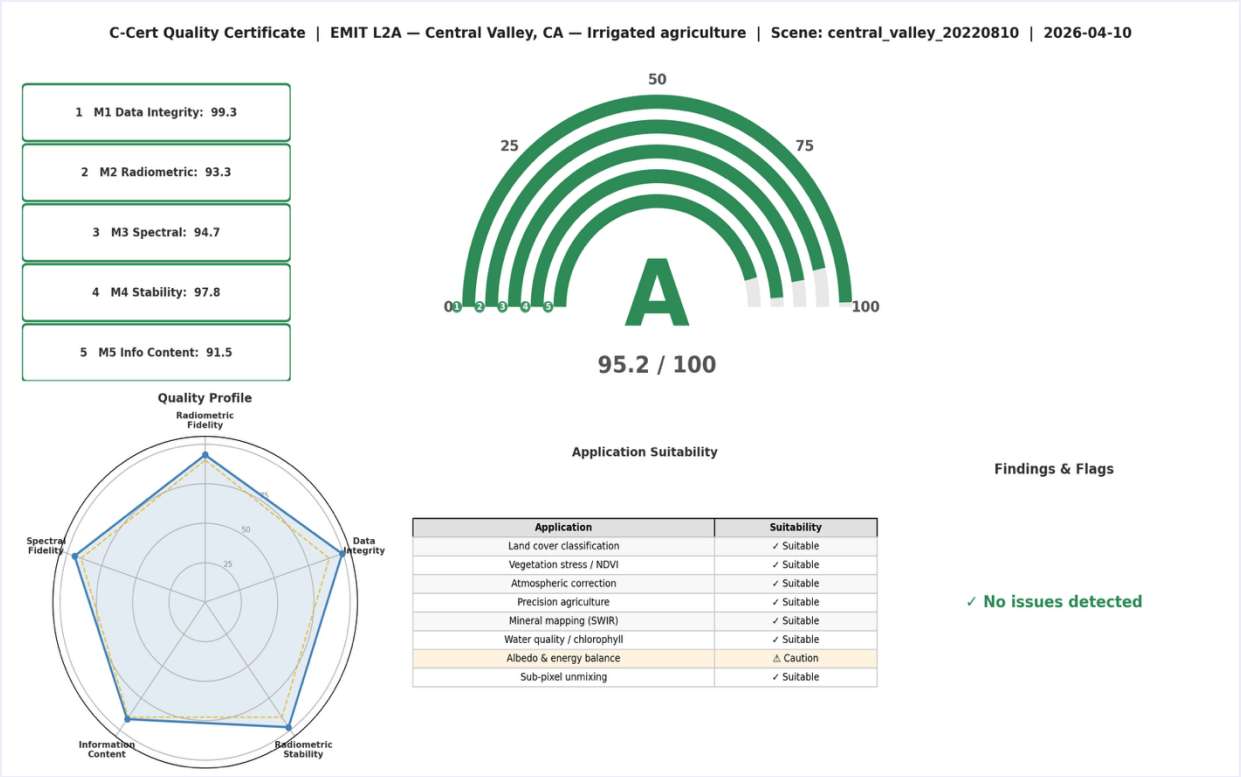
M5: Scene Composition & Unmixing Residual



Interpretation

- Based on Sousa & Small (2023) — joint characterization via spectral unmixing + manifold learning.
- Left: True-color RGB of Cuprite showing diverse mineralogy, playa, and alluvial surfaces.
- Center: SVD-based surface classification map — five endmember classes (bright soil/playa, vegetation, impervious/urban, mineral) resolved from spectral unmixing.
- Right: Unmixing residual map — lower values (darker) indicate better spectral fit. Higher residuals in mineral-rich zones reflect complex absorption features beyond the reference endmember set.
- Overall low residuals confirm EMIT captures sufficient spectral information for robust surface characterization.

C-Cert Report Card: Cuprite EMIT



95.2

out of 100 • Grade A

- Five independent modules confirm EMIT data quality at Cuprite exceeds requirements for scientific analysis.
- All modules scored A individually
- Application suitability matrix confirms fitness for land cover, mineral mapping, atmospheric correction, and more.
- Certificate provides traceable, reproducible evidence of fitness-for-purpose.

C-Cert creates a win-win: government gets trusted, interoperable data — commercial providers gain credibility, faster contracts, and market differentiation.

Thank You

- C-Cert delivers automated, reproducible quality certificates for any EO sensor
- Extensible to any sensor: VIIRS, GOES-R, Landsat, commercial providers
- Goal: offer C-Cert as a product/service for operational data quality assurance
- C-Cert creates a win-win: government gets trusted, interoperable data — commercial providers gain credibility, faster contracts, and market differentiation.

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