

Night-time Satellite and Aerial Image Denoising with Online Complex Noise Modeling and Deep Learning



Sandeep Kumar Jangir, Dr. Tobias Storch

Remote Sensing Technology Institute, German Aerospace Centre (DLR), Germany
sandeep.jangir@dlr.de , tobias.storch@dlr.de

ESA - LIVING PLANET SYMPOSIUM

Significance of Night-time Imagery

- Global Relevance:** At any moment, half of Earth's surface is in night-time, yet most remote sensing focuses on daytime imaging.
- Human Activity Insights:** Artificial lighting drives night-time activities, reflecting social factors like wealth and urban development.
- Environmental Impact:** Night-time light emissions reveal light pollution, affecting ecosystems and energy consumption.

Approach

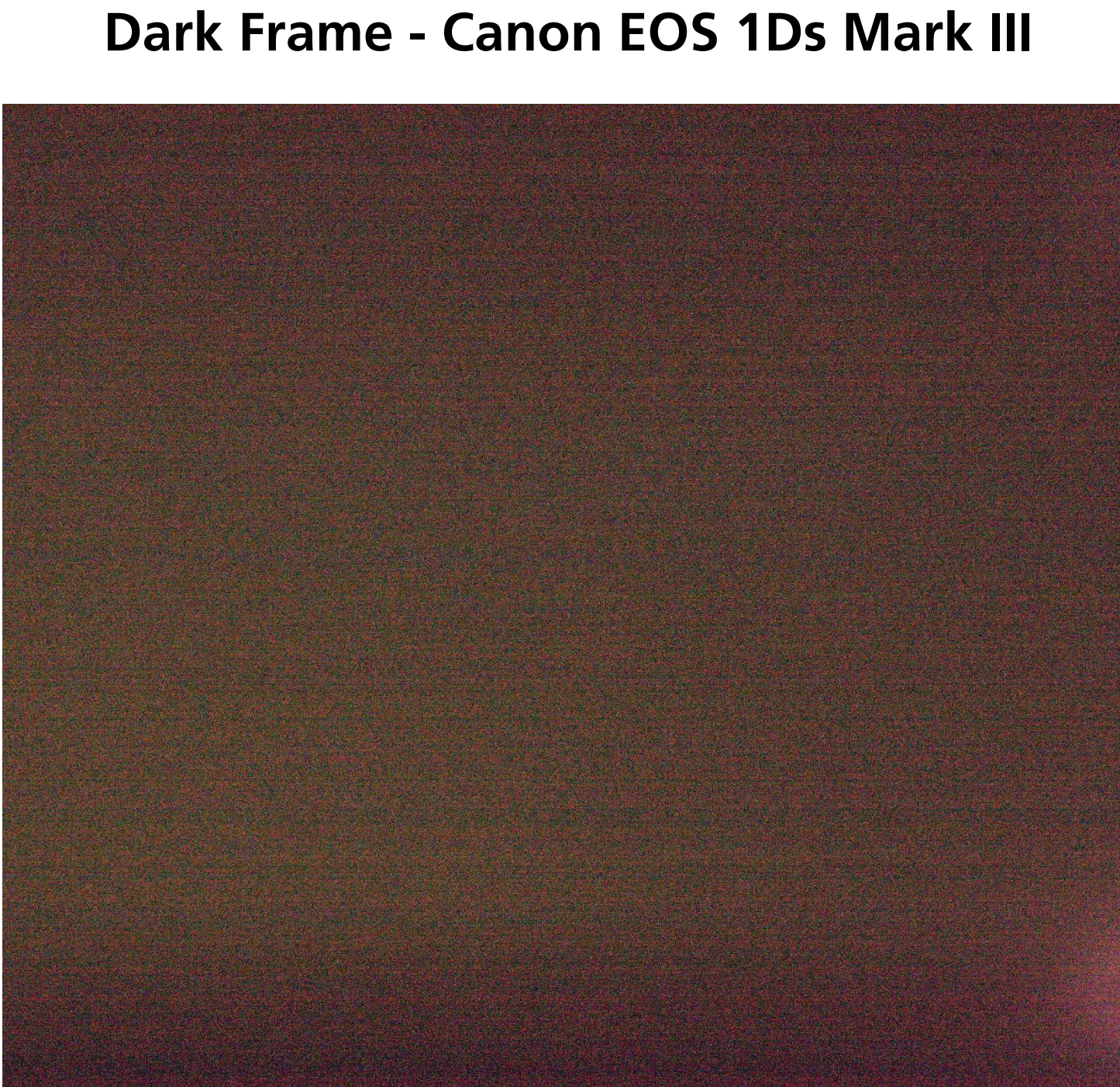
- Dark Frame Analysis:** Analyzed aerial dark frames to pinpoint noise: hot/dead pixels (R, G, B), banding, FPN, and random (dark current, shot, read).
- Noise Degradation:** Simulated realistic noise (hot/dead pixels, banding, FPN, random) for 8/12/16-bit depths with diverse patterns.
- Lightweight DNN Design:** End-to-end trainable deep neural network (DNN) with 20K parameters optimized for low-light denoising and suitable for real-world deployment
- Noise Injection:** Aerial images injected with varied noise combinations and intensities during training; online injection creates unique mini-batch patterns, boosting generalization.
- Native Noise Removal:** Post-training, the DNN efficiently processes raw test images, effectively removing native noise artifacts to enhance image quality.

Challenges :

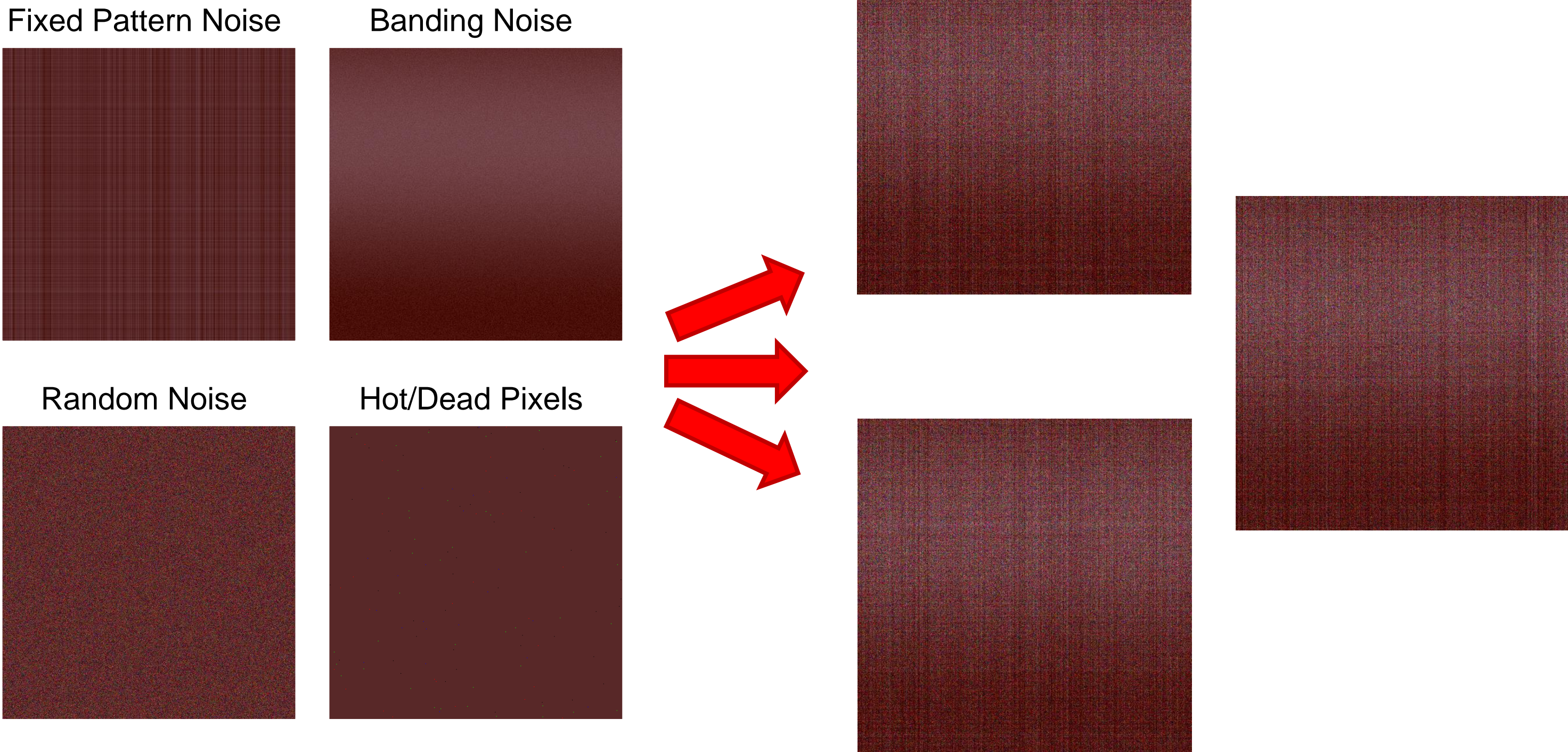
- Sensor Limitations:**
 - Low spatial resolution restricts detail capture in aerial and satellite images.
 - Limited spectral information hinders material and feature identification.
 - Poor radiometric sensitivity reduces signal detection in low-light conditions.
 - Infrequent revisits limit timely monitoring of dynamic events.
- Complex Noise Artifacts:**
 - Hot/Dead Pixels: Defective pixels stuck at R, G, B (bright) or black (dark) values in both aerial and satellite sensors.
 - Banding Noise: Gradient-like readout or amplifier glow artifacts, prominent in long-exposure dark frames.
 - Fixed-Pattern Noise (FPN): Column/row variations from sensor non-uniformity, affecting both platforms.
 - Random Noise: Dark current (thermal), shot, and read noise degrade low-light signals.
- Impact of Noise:**
 - Reduces signal-to-noise ratio, impairing classification, detection, and damage assessment.
 - Exacerbates challenges in low-light aerial and satellite imagery analysis.
- Traditional Methods Fail:**
 - Filtering (e.g., Gaussian, median) cannot address diverse, ill-posed noise patterns.
 - Scarcity of paired noisy-clean datasets limits training for denoising models.

Noise Degradation

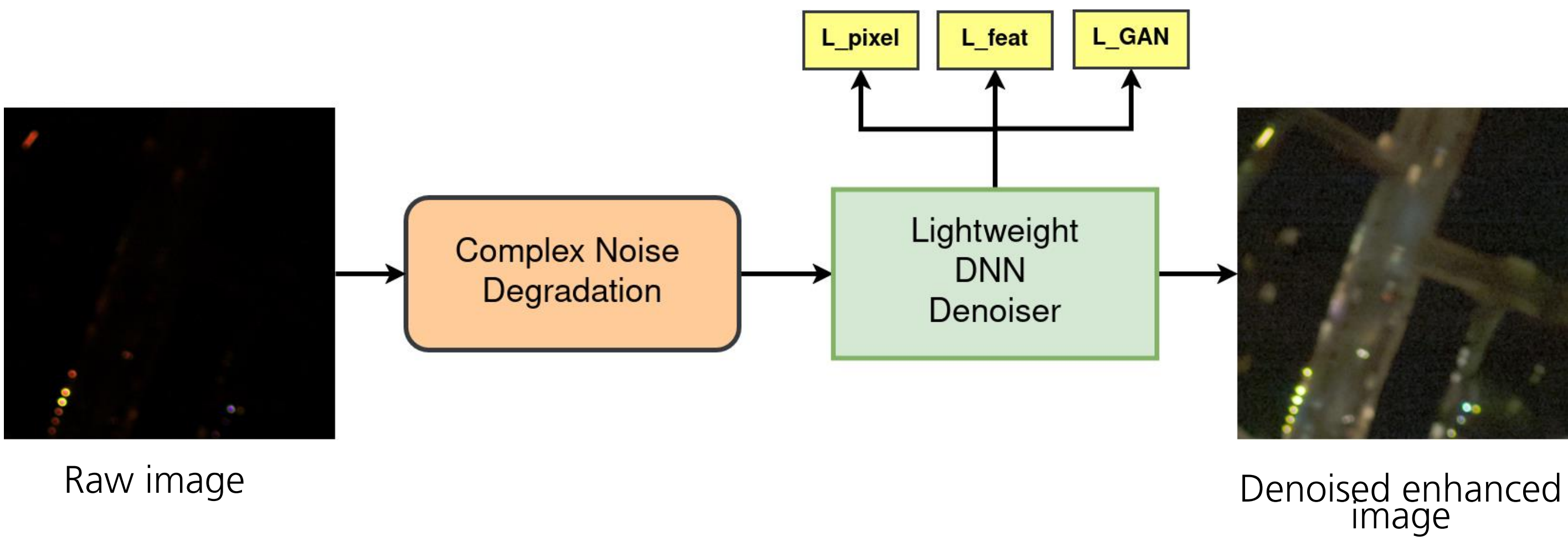
- Dark Frame:** Closed-shutter image capturing noise (hot/dead pixels, banding, FPN, random) in low-light.
- Noise Patterns:** Reveals specific noise types (e.g., FPN, banding) for realistic modeling.
- Intensity Data:** Offers noise amplitude and distribution for varied simulation intensities.
- Sensor Artifacts:** Highlights sensor-specific defects (e.g., hot pixel, sensor degradations) to refine degradation parameters.



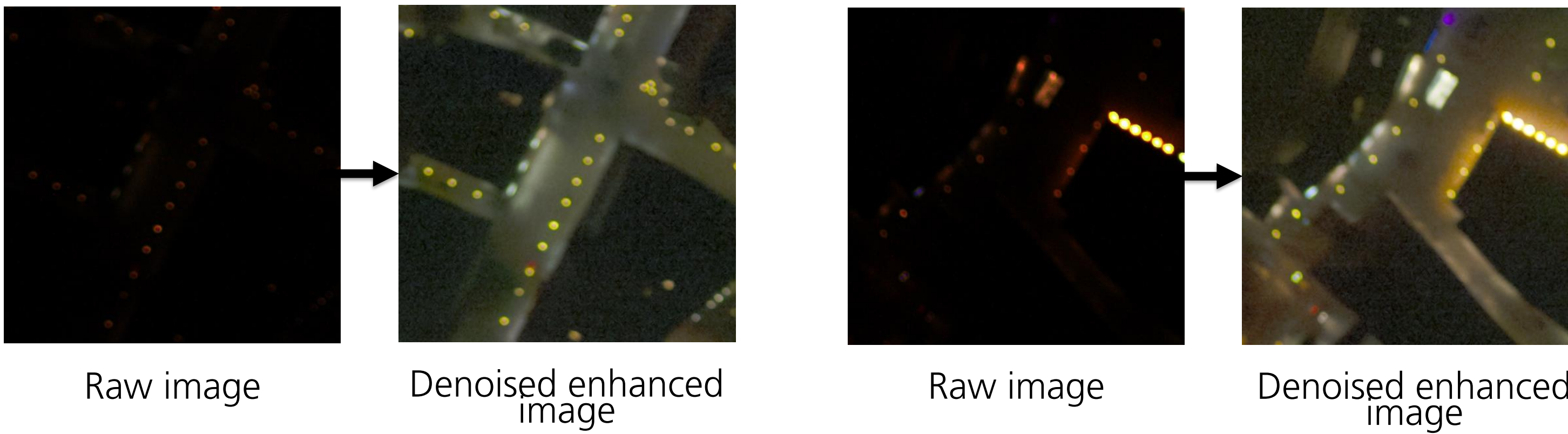
Noise Simulation



DNN Denoiser

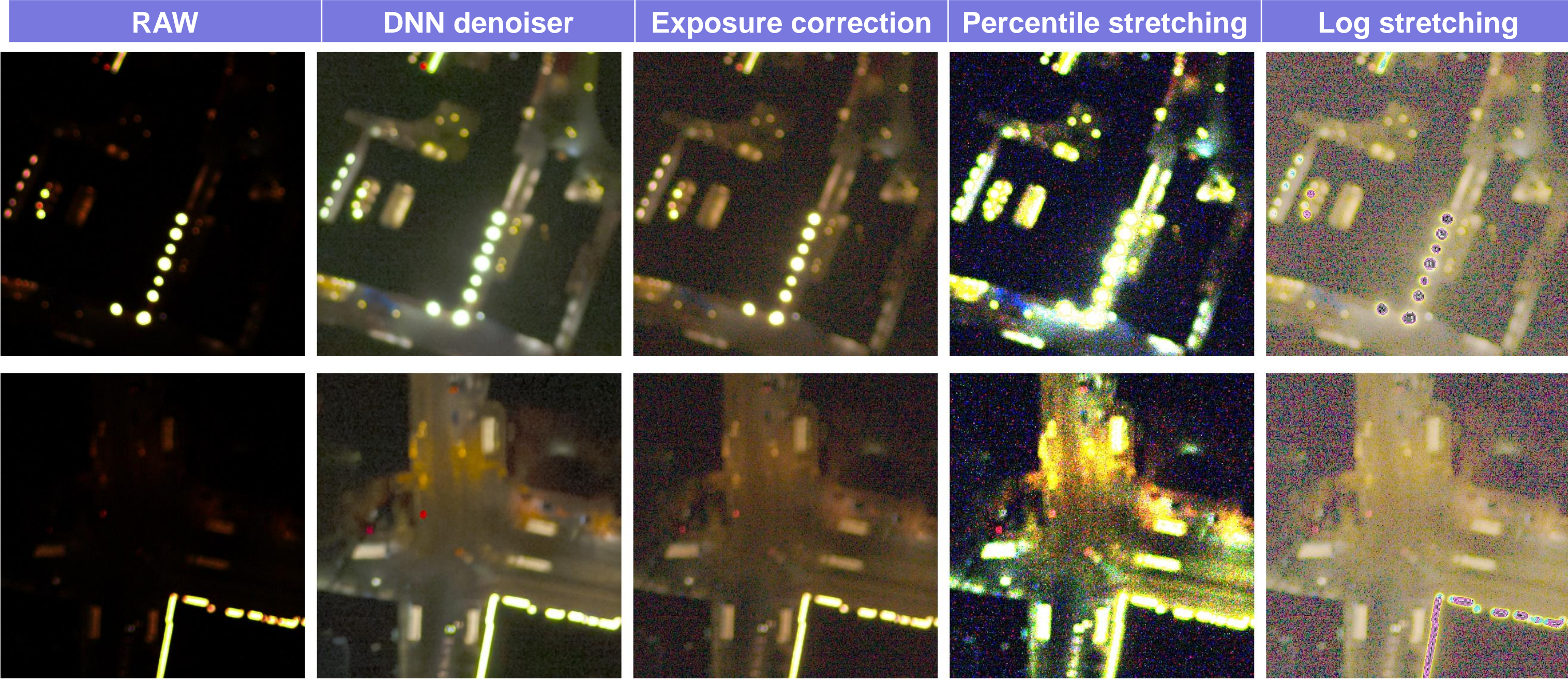
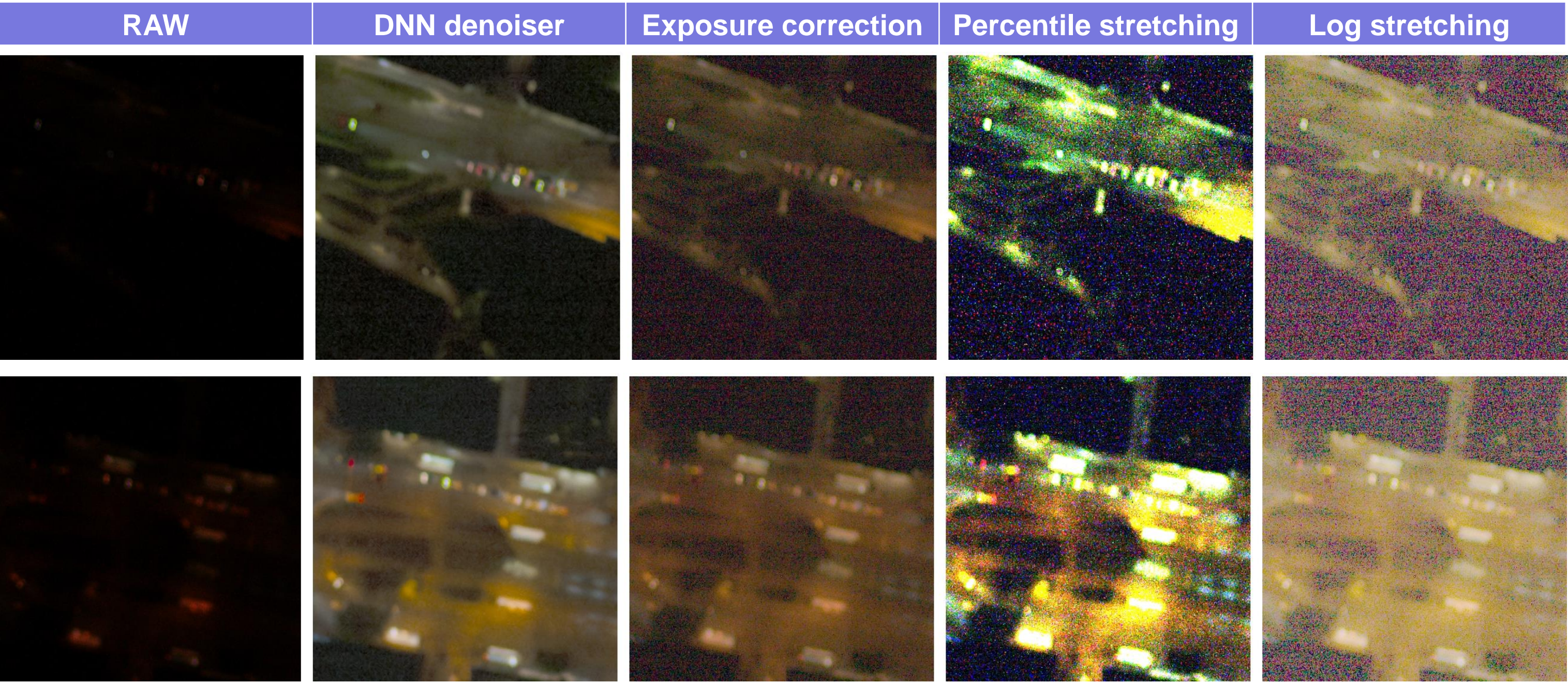


Results



Real-World Processing

- Raw night-time images are adjusted via exposure or percentile stretching for proper exposure, enabling downstream tasks like street lamp classification.
- The DNN denoiser removes noise and enhances images, allowing direct use in downstream applications with improved quality.



Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

DLR – German Aerospace Center
Remote Sensing Technology Institute
D-82234 Weßling
<http://www.dlr.de/>

