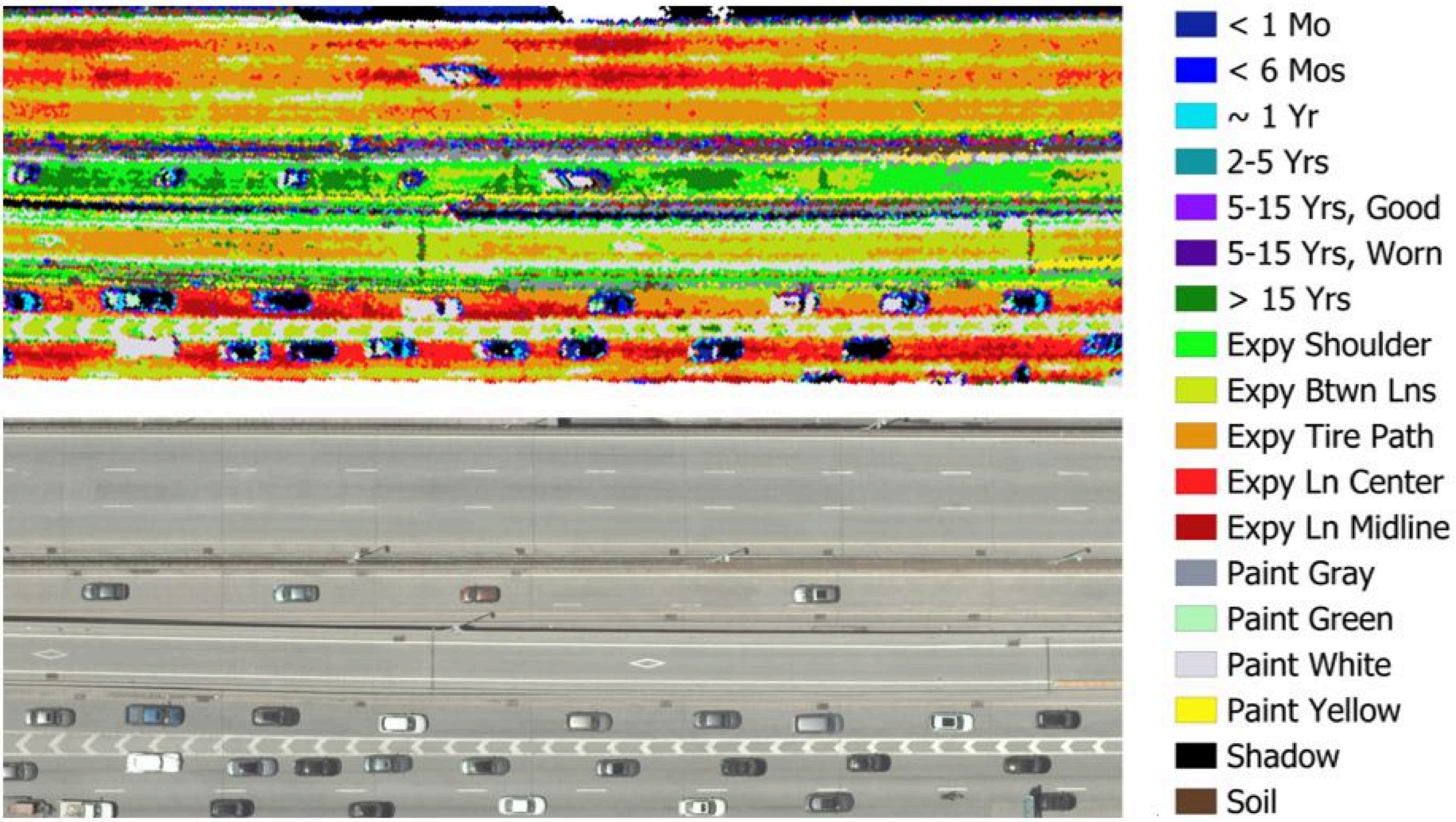
CITIES IN FULL COLOR: HOW HYPERSPECTRAL IMAGING IS REWRITING WHAT WE KNOW ABOUT URBAN MATERIALS



"...America's roadway and bridge infrastructure will need a $1.1 trillion dollar investment over the next two decades according to the Federal Highway Administration..."

Stand on a city street and look down. The asphalt beneath your feet seems predictable, flat, dark, and familiar. But every road, roof, bridge, and wall in a city is constantly changing. Materials breathe, crack, cure, dry, blister, and erode. These transformations shape the lifespan of infrastructure, yet most unfold invisibly, beyond the reach of human vision.

Recent research led by Jessica Salcido and Professor Debra Laefer at New York University invites us to see the city differently - spectrally. Using airborne hyperspectral imagery collected with the ITRES microCASI-1920 VNIR sensor, their work reveals the complex, evolving material signatures of urban environments with unprecedented clarity.

This article brings together findings from two of their recent studies: one diagnosing a global shortage of urban spectral reference data and the other demonstrating how hyperspectral imaging can classify pavement age and wear patterns across active, complex roadways in New York City.

THE MISSING DICTIONARY: A GLOBAL GAP IN URBAN SPECTRAL REFERENCES

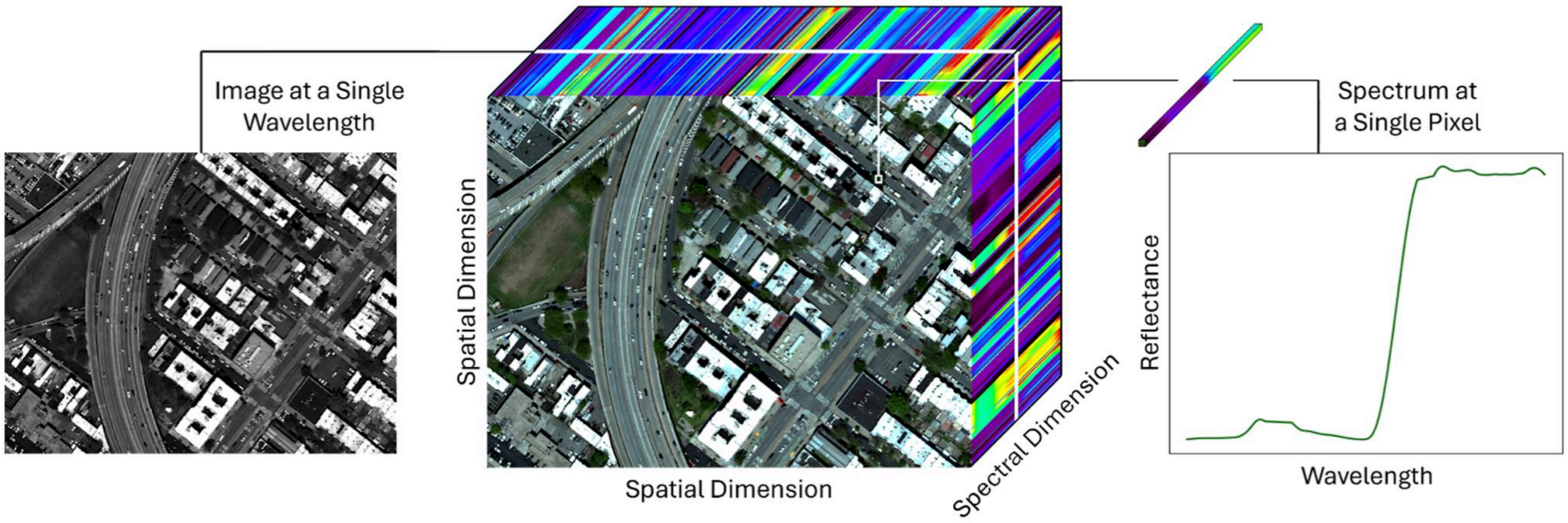
Hyperspectral remote sensing goes beyond the familiar red, green, and blue of a typical camera. It works by measuring how much light a surface reflects across hundreds of narrow wavelength intervals, including regions visible and invisible to the human eye, to create a detailed spectral signature unique to each material.

But to identify a material, a hyperspectral sensor first needs something essential: a trustworthy reference spectrum to compare against. When Salcido and Laefer examined existing spectral libraries, they found a surprising gap. Urban materials (the concrete, asphalt, metal, and other surfaces that make up the building blocks of cities) are strikingly underrepresented.

Despite the ubiquity of man-made structures, of a total of **476,592** publicly accessible spectral signatures, only **0.61%** represent urban materials.

Even within that miniscule fraction, many entries lack essential metadata such as material age, coatings or finishes, manufacturing process, moisture content, viewing geometry, environmental exposure and other important descriptors valuable for analysis.

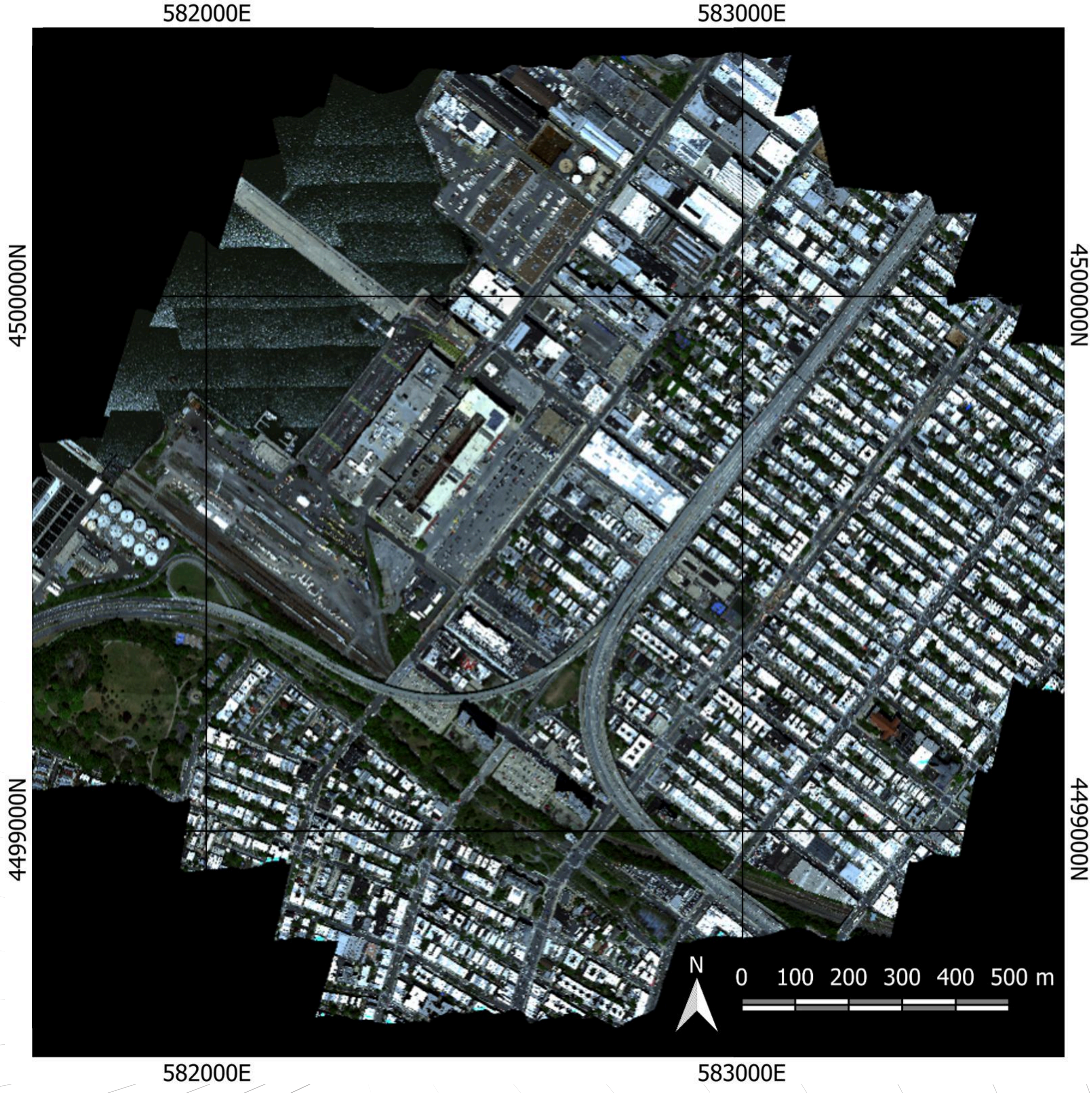
Based on: Urban hyperspectral reference data availability and reuse: State-of-the-practice review, Salcido & Laefer (2024)



Two road samples may be visually identical, yet have distinct spectral characteristics. The limited availability of urban material spectra, and the severe lack of metadata describing the exact material properties, means there is very little against which newly collected spectra can be reliably compared, making definitive identification challenging.

Urban materials pose unique challenges: asphalt oxidizes, concrete cures, coatings deteriorate, and roofing composites degrade at different rates depending on pollution and climate. Salcido and Laefer respond to this challenge by proposing a 14-element metadata framework tailored for urban materials. It includes not just spectral conditions but also physical descriptions, production context, and performance characteristics forming the basis of a future urban spectral "dictionary."

THE PAVEMENT STUDY: SEEING ROADWAYS IN SPECTRAL DETAIL

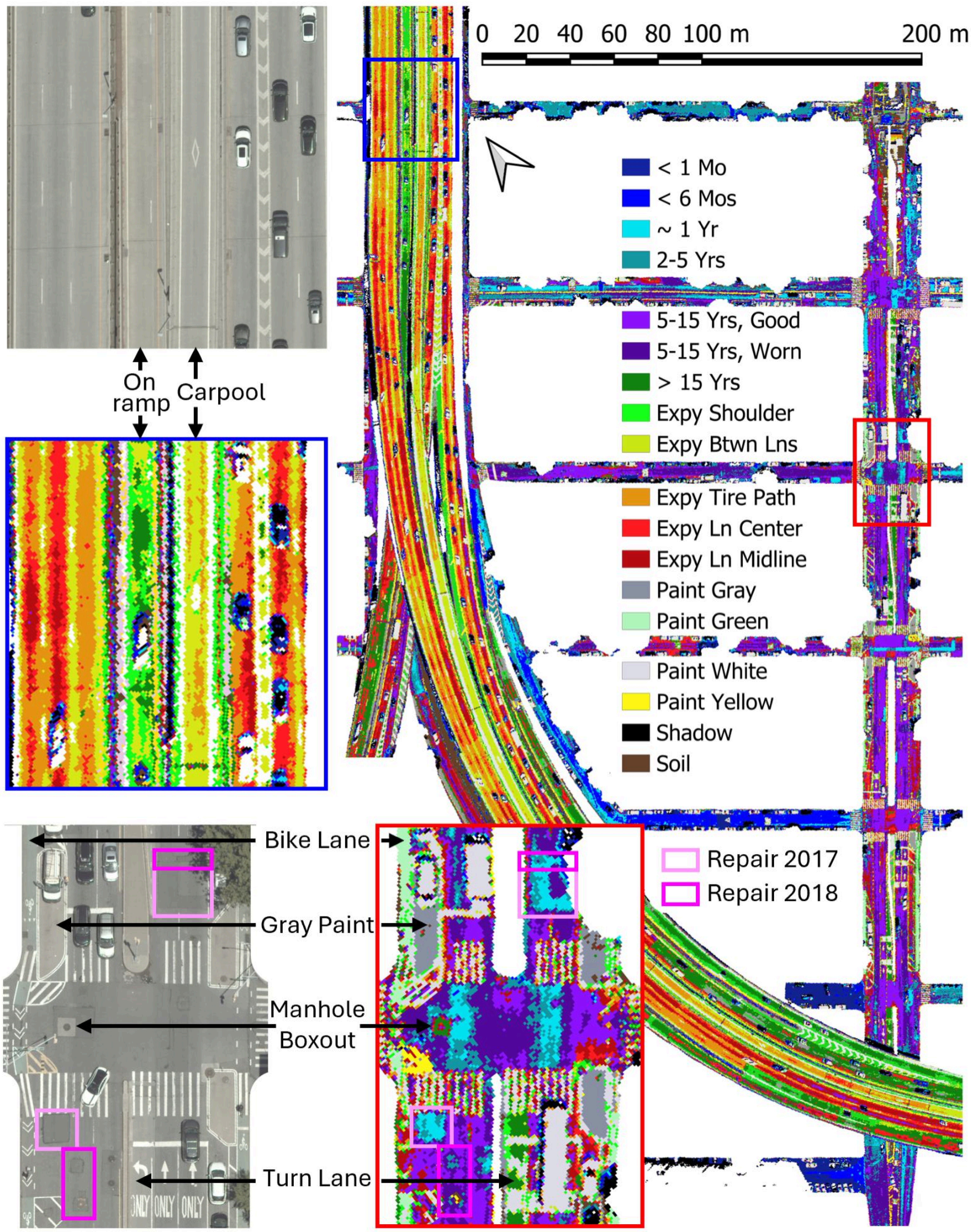


Based on: Intra-Roadway Pavement Assessment via Aerial Hyperspectral Imagery, Salcido et al. (2025)

While the first study exposes gaps in existing resources, the second demonstrates what is now achievable with high-quality hyperspectral data and a rigorous scientific methodology. Using the ITRES microCASI-1920 sensor, VNIR data was acquired via helicopter over Sunset Park, Brooklyn. The research team classified pavement age groups, resurfacing patches, and lane-specific wear zones. Despite the small training set (472 pixels), a Support Vector Machine (SVM)[1] with RBF (Radial Basis Function) kernel[2] achieved ~89% accuracy across 18 classes.

[1] An SVM is a type of machine-learning model used to separate data into categories—in this case, different pavement ages and wear zones.

[2] The "RBF kernel" (Radial Basis Function kernel) is a mathematical tool that helps the model draw flexible boundaries between classes when the data aren't cleanly separated. In practical terms, it allows the classifier to handle subtle, nonlinear differences in pavement reflectance patterns.



0 20 40 60 80 100 m 200 m
< 1 Mo
< 6 Mos
~ 1 Yr
2-5 Yrs
5-15 Yrs, Good
5-15 Yrs, Worn
> 15 Yrs
Expy Shoulder
Expy Btwn Lns
Expy Tire Path
Expy Ln Center
Expy Ln Midline
Paint Gray
Paint Green
Paint White
Paint Yellow
Shadow
Soil
On ramp
Carpool
Bike Lane
Gray Paint
Manhole Boxout
Turn Lane
Repair 2017
Repair 2018

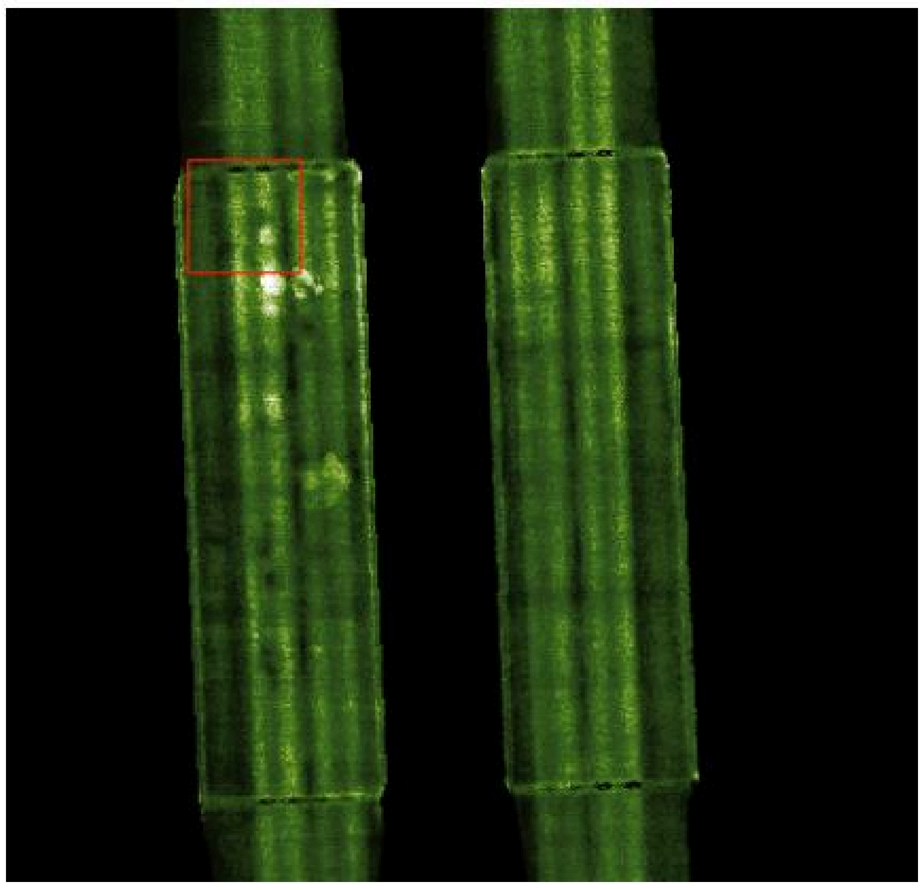
ITRES

Key insights include:

- Roadway repairs were not only separable from the adjacent pavement but could be assigned consistent age estimates, which were independently validated using satellite imagery.
- Newly laid pavement was accurately separable into 3 age-based classes: < 1 month, < 6 months, or ~1 year.
- Pavement older than 15 years forms its own consistent spectral group.
- Lane based wear differed by region even within a single lane, as well as across different lanes in predictable ways based on traffic volume.

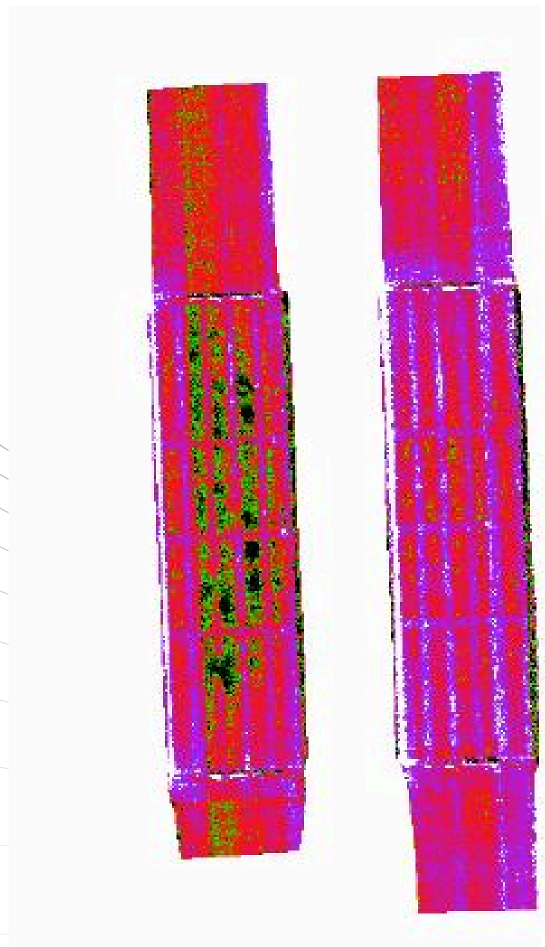
Salcido and Laefer's work demonstrates that hyperspectral data captures pavement history, revealing that information normally buried in permits and inspections can instead be read directly from the light pavement reflects.

A GROWING NUMBER OF TOOLS IN THE TOOLKIT

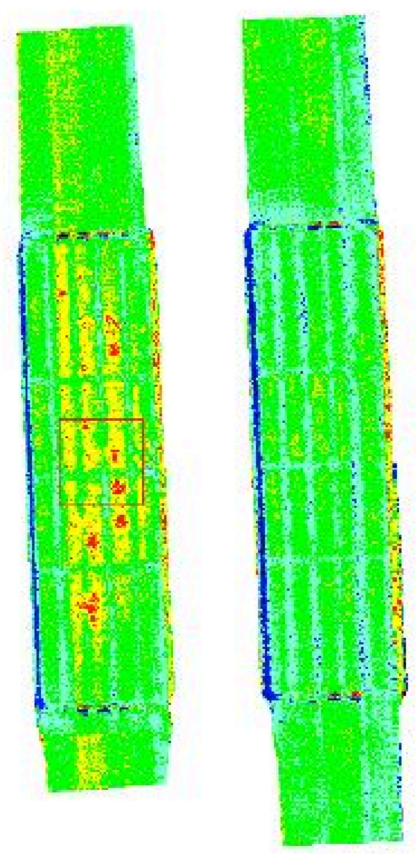


1am Thermal dataset (0.25m GSD)

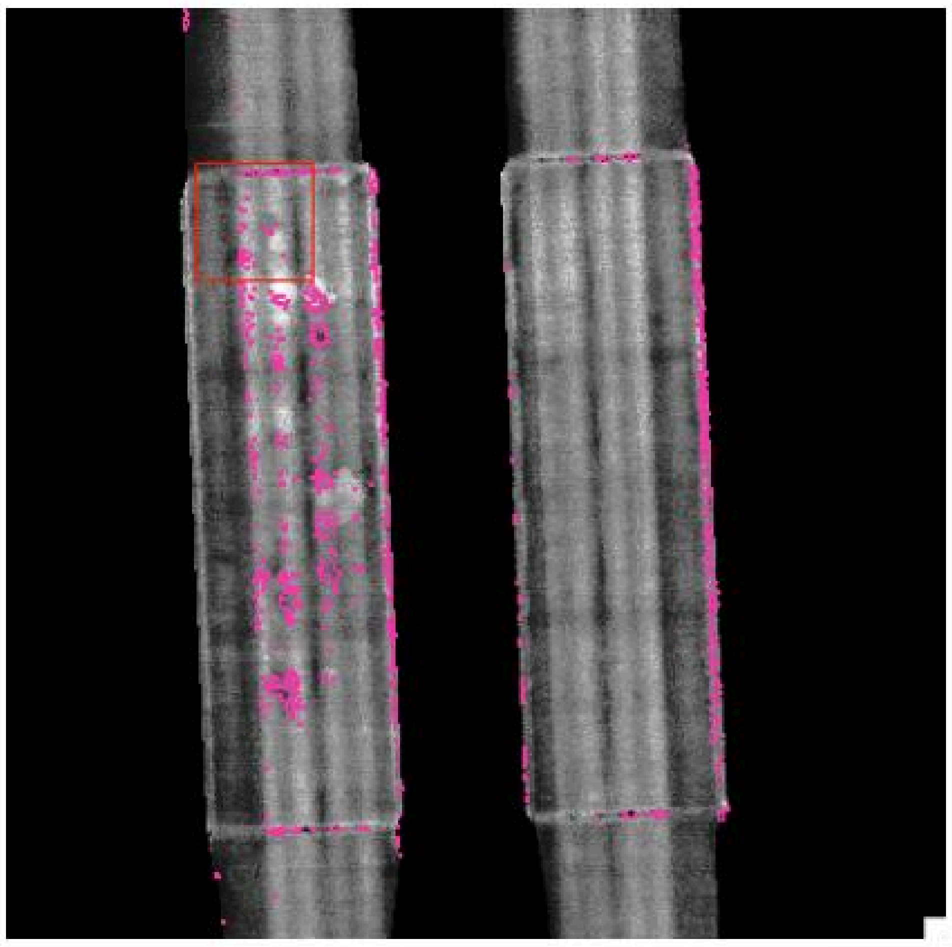
Google Earth Image (Captured within 6 months of the thermal acquisition)



Heat Differential Over Time



Classified Heat Differential



Heat Differential Classification over initial Thermal Image

While Salcido and Laefer's research focuses on the visible near infrared domain, their findings fit into a growing multimodal approach to urban remote sensing. For example, thermal infrared imaging such as generated by the ITRES TABI-1800 sensor has been used in city infrastructure to reveal subsurface anomalies in bridge decks, heat-retention patterns on overpasses, and moisture-related deterioration invisible in optical data.

> The combination of hyperspectral and thermal data sets has the potential to reveal a treasure trove of insights to better manage and maintain roadways.

WHY DOES IT MATTER?

Public roadways connect communities, support economies, and shape daily life, yet they are aging, stressed by climate change, and becoming more expensive to maintain. According to the American Society of Civil Engineers' 2025 Report Card, America's 4.1 million mile road network earns a D+, with 39% of major roads in poor or mediocre condition. The Federal Highway Administration estimates that addressing the nation's backlog of highway and bridge needs will require $1.1 trillion over the next two decades.

Keeping roads in good condition saves governments money, reduces vehicle repair costs for individuals, and most importantly, protects lives. But infrastructure investment will never be limitless, and no city can repair everything at once. What is needed is a new paradigm of monitoring that reveals where repairs are most urgent and where aging is accelerating. Traditional inspections rely on staff availability, subjective assessments, and what the human eye can detect. Remote sensing, especially hyperspectral data, shifts the paradigm by providing objective, material-level data, city-scale coverage at sub-meter resolution, change detection over time, early warnings for maintenance, and greater accountability in resurfacing and construction.

As spectral libraries grow and methodologies like those developed by Salcido and Laefer mature, cities will be able to move from reactive maintenance to proactive management guided by data that goes deeper than what the eye can see, making every maintenance dollar count while keeping people safer.

CONCLUSION

It could be said that cities hide their material stories in plain sight. Salcido and Laefer's work show that these stories can now be read with clarity, whether in the repair history of a small pothole or the long-term, dynamic wear of an entire roadway. Their findings lay the groundwork for a future where the health of a city is continuously monitored in spectral space, its materials understood not just by appearance but by composition, age, and performance.

As spectral libraries expand and pioneering researchers like Salcido and Laefer continue to demonstrate what hyperspectral imaging can do in real urban environments, cities will become legible in ways once thought impossible. The invisible will become visible and with it, the possibility of maintaining urban life with precision, foresight, and care. Because when you see more, you know more.