

# VISUALIZING EXTREME HEAT DISPARITIES

LESSONS FROM THE LAF-FUNDED "HEAT WAVES" RESEARCH PROJECT



## 1.0 LA CES CEU (HSW)



- Link to quiz in the chat + follow-up email
- 1.0 PDH (HSW) issued upon completion of 10-question quiz with a score of at least 75%
- Retakes allowed
- Certificate will be emailed **within 2 weeks**

**INCREASE** the  
**INFLUENCE**  
and **IMPACT** of  
landscape  
architects

## LANDSCAPE ARCHITECTURE FOUNDATION

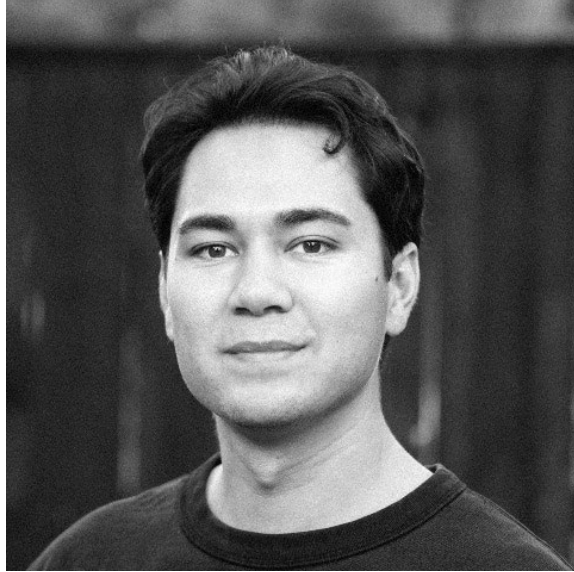
- 501(c)(3) nonprofit based in Washington, DC
- Invested over **\$3 million** in research since 1986
- Awarded over **\$2 million** in scholarships to over **650** students since 1986
- Awarded **\$440,000** to **31** professionals to support innovation and leadership since 2017
- Cultivating the **next generation** of leaders by investing in landscape architects

# LAF DEB MITCHELL RESEARCH GRANT



- Deb Mitchell, FASLA + SmithGroup
- Research projects that are relevant and impactful for the professional practice of landscape architecture
- 1 award of \$25,000
- Principal Investigator must be trained as a landscape architect
- 12 to 18 months, beginning in summer or fall
- Pre-proposals due December 1

# PRESENTERS



**Salvador Lindquist**

Assistant Professor  
University of Nebraska



**Keenan Gibbons, PLA, LEED Green**

Landscape Architect, SmithGroup  
Lecturer, University of Michigan

# INTRODUCING THE THERMAL TOOLKIT:

TECHNOLOGIES AND TECHNIQUES FOR VISUALIZING THERMAL DISPARITIES

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2024 LAF WEBINAR



## ABSTRACT:

Extreme heat kills more people in the United States than any other natural disaster (BERKO 2010). These effects are more pronounced in urban environments, where buildings, roads, and other infrastructure absorb and re-emit the sun's heat, otherwise known as urban heat island effect. The increasing frequency and intensity of extreme heat in urban environments pose significant public health risks, disproportionately impacting underserved populations. While heat action plans have gained traction as a process for mitigating the unequal distribution of intense surface temperatures, there is a need for more granular data to guide site-scale landscape planning decisions. The prevailing method of measuring Land Surface Temperature (LST) using United States Geological Survey (USGS) remote sensing data can only reach a resolution of 30m x 30m, and often overlooks the lived reality of the impacts of extreme heat. **This study uses UAV thermography and handheld thermal imagery to visualize the hyper-localized impacts of the urban heat island effect by applying these technologies through a comparative study of three urban corridors in Omaha, Nebraska: 75 North, Regency, and the Gene Leahy Mall.** Not only can thermo-visualization technologies improve landscape decision making, it can improve the transdisciplinary processes that contribute to consensus building by making the distribution of extreme heat more tangible.





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01

# INTRODUCTION: HEATING UP!

- A The Toolkit
- B Climate Change
- C Urban Heat Island Effect
- D Thermal Comfort/Disparity



OUTFRONT / JCDecaux

HD099

Extreme heat is one of the **leading causes of natural disaster-related deaths** in the United States, and the problem is expected to worsen as the effects of climate change intensify (Berko, 2014).

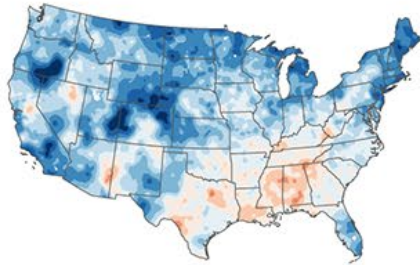


This is the **HOTTEST** summer of my life

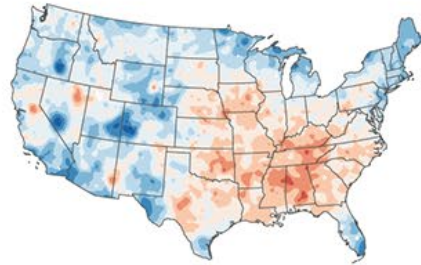
This is the **COLDEST** summer of the rest of your life

# U.S. ANNUAL TEMPERATURE COMPARED TO 20<sup>th</sup>-CENTURY AVERAGE

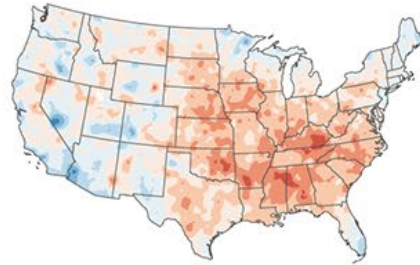
1901-1930



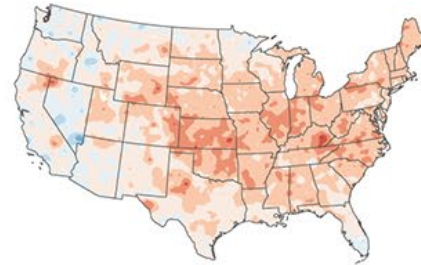
1911-1940



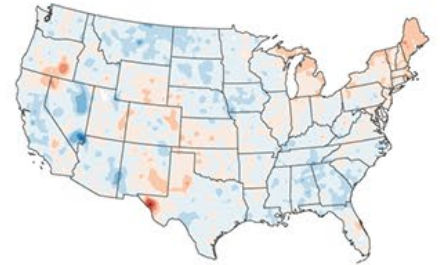
1921-1950



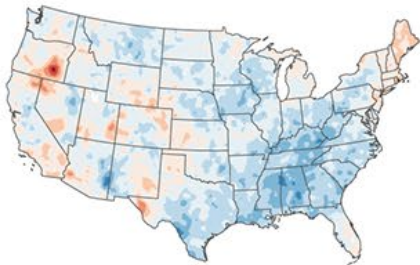
1931-1960



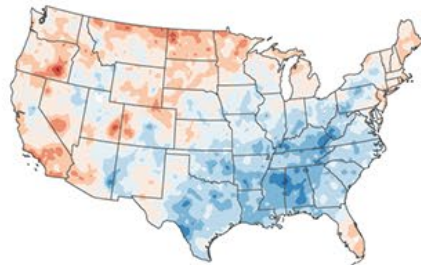
1941-1970



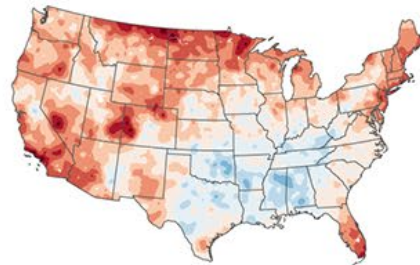
1951-1980



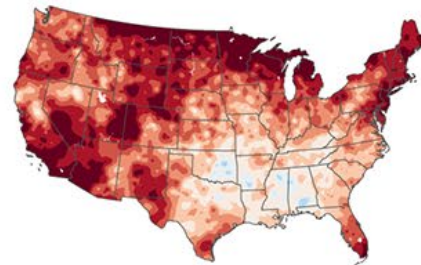
1961-1990



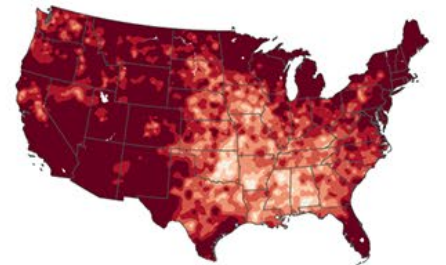
1971-2000



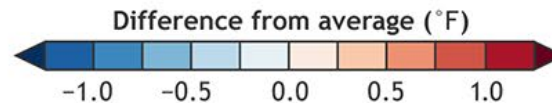
1981-2010




1991-2020




30-year Normal  
compared to 1901-2000



NOAA Climate.gov  
Data: NCEI



Urban environments are particularly vulnerable to the heat, with hotter temperatures in areas with higher concentrations of concrete and asphalt (EPA, 2022).



Today, researchers think of the **heat island as more of an archipelago**, where hot spots are heterogeneously distributed throughout a city in locations with higher concentrations of concrete and asphalt, whereas **cooler temperatures can be found around trees, parks, or other open space** (Borunda, 2021).

A photograph of a man on a skateboard in a hot city street. The man is wearing a silver bucket hat, sunglasses, a white t-shirt with 'REGRE' visible, plaid shorts, white socks, and white sneakers. He has a black backpack and is holding a phone to his ear. The street is paved and has white lane markings. In the background, there are several buildings, including a tall blue skyscraper and a white building with a 'ONE' sign. The sky is blue with some clouds. A group of people is visible on the sidewalk to the left, and some debris is on the ground to the right.

**Underserved populations are disproportionately affected by heat waves**, and the growing frequency and intensity of extreme heat pose a significant public health threat.



M. H. LA DOUCEUR  
DESIGNER-ENGROSSER-DRAFTSMAN  
936 CITY NAT'L BANK BLDG.,  
OMAHA, NEB.

MAP MAKING A SPECIALTY  
PHONE YOUR  
MAP WANTS TO  
JACKSON 5373

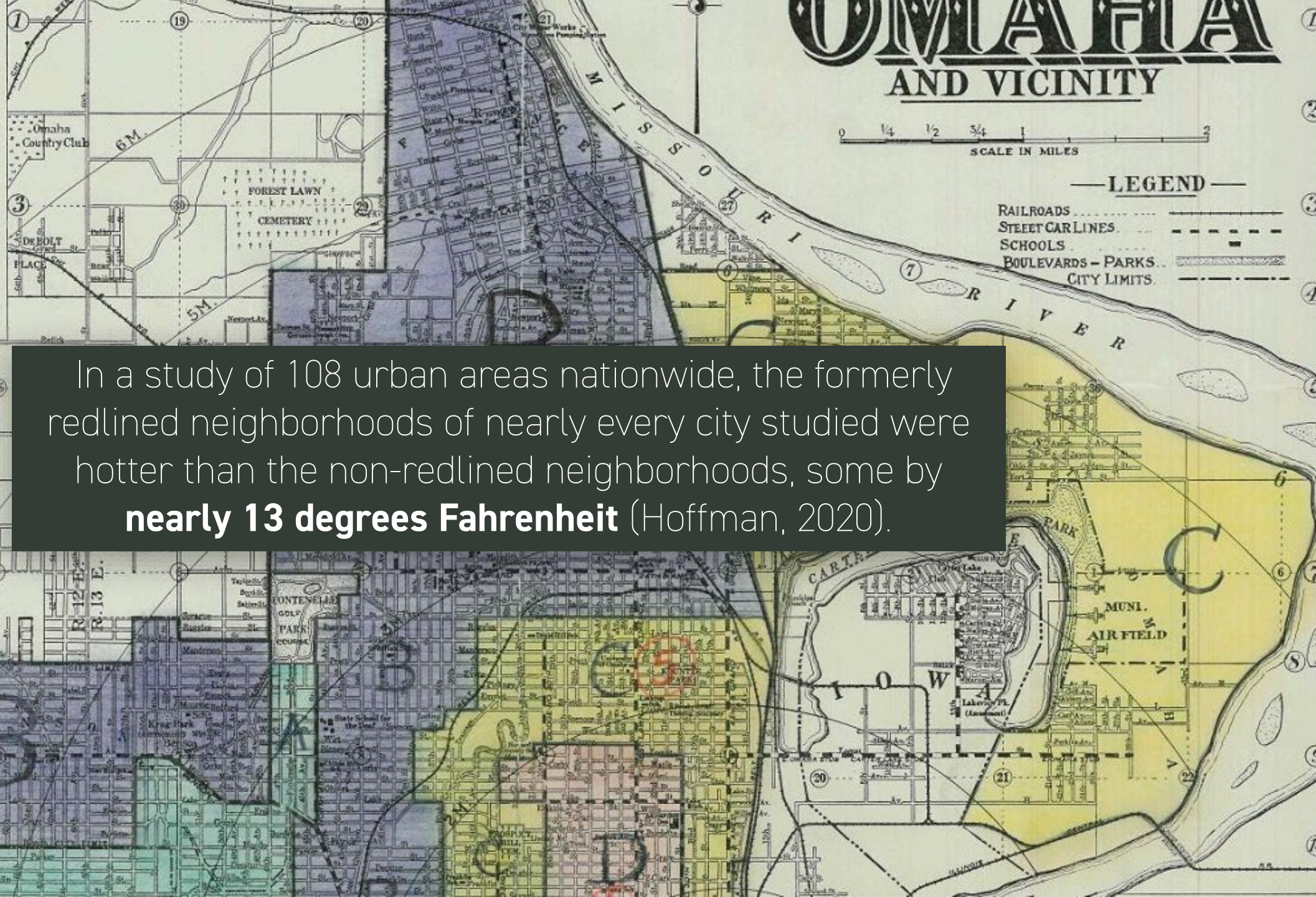
STATES, COUNTIES, CITY  
AND  
AUTOMOBILE MAPS  
ALWAYS ON HAND

# OMAHA AND VICINITY

0 1/4 1/2 3/4 1 2  
SCALE IN MILES

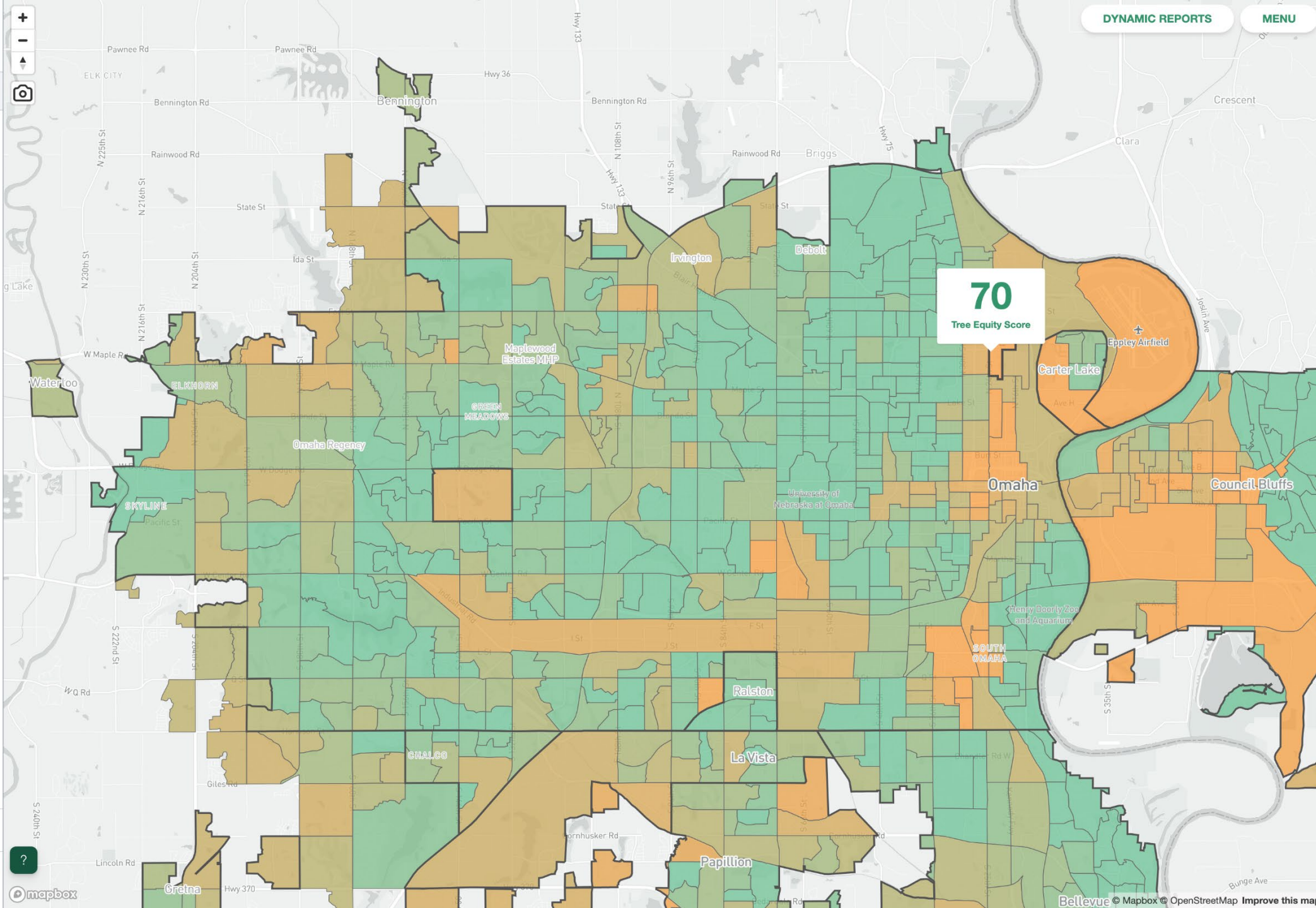
## — LEGEND —

RAILROADS .....  
STREET CAR LINES .....  
SCHOOLS ■  
BOULEVARDS - PARKS .....  
CITY LIMITS - - - - -



In a study of 108 urban areas nationwide, the formerly redlined neighborhoods of nearly every city studied were hotter than the non-redlined neighborhoods, some by **nearly 13 degrees Fahrenheit** (Hoffman, 2020).

Search for a location



**Census Block Group 310550008001**

Population: 1,184

Omaha, NE

NE Congressional District 2

**70**

Tree Equity Score

Ranked 451st of 462 block groups in Omaha

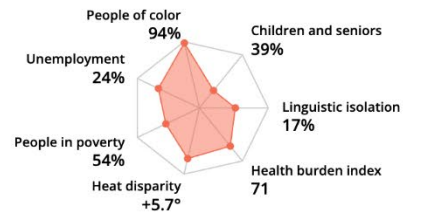
Priority: **HIGH**

Current canopy cover: 16%



**Score indicators**

Priority index



**70**  
Tree Equity Score

Layers Filters



A vibrant, modern urban plaza with lush greenery, people, and tall buildings. The scene is filled with people walking, sitting on the grass, and playing in a fountain. The architecture is a mix of modern glass skyscrapers and older, more traditional buildings. The overall atmosphere is bright and lively, with a clear blue sky and abundant sunlight.

“Shade is often understood as a luxury amenity. But as deadly heatwaves become commonplace, we have to see it as **a civic resource shared by all.**” (Bloch, 2019)

A photograph of a modern urban walkway. In the foreground, a paved path leads past a row of parked bicycles. To the right of the path is a lush green garden bed with small purple flowers. Large, mature trees with thick, gnarled trunks and dense green foliage line the path, casting shadows. In the background, a modern building with large glass windows and a balcony with pink flowers is visible. Several people are walking along the path, including a woman in a floral dress and a woman in a grey t-shirt. The overall scene is bright and sunny, suggesting a pleasant urban environment.

Mitigating the unequal distribution of intense surface temperatures requires a multifaceted approach, including **policy, public health, urban planning, and nature-based solutions.**

02

# HEAT, DESIGN, ACTION!

**A** Planning for Urban Heat Resilience

**B** Resources for Resilience



## Heat Action Planning Guide

FOR NEIGHBORHOODS OF GREATER PHOENIX

Creating Urban Heat Solutions in the Valley of the Sun

WSROC

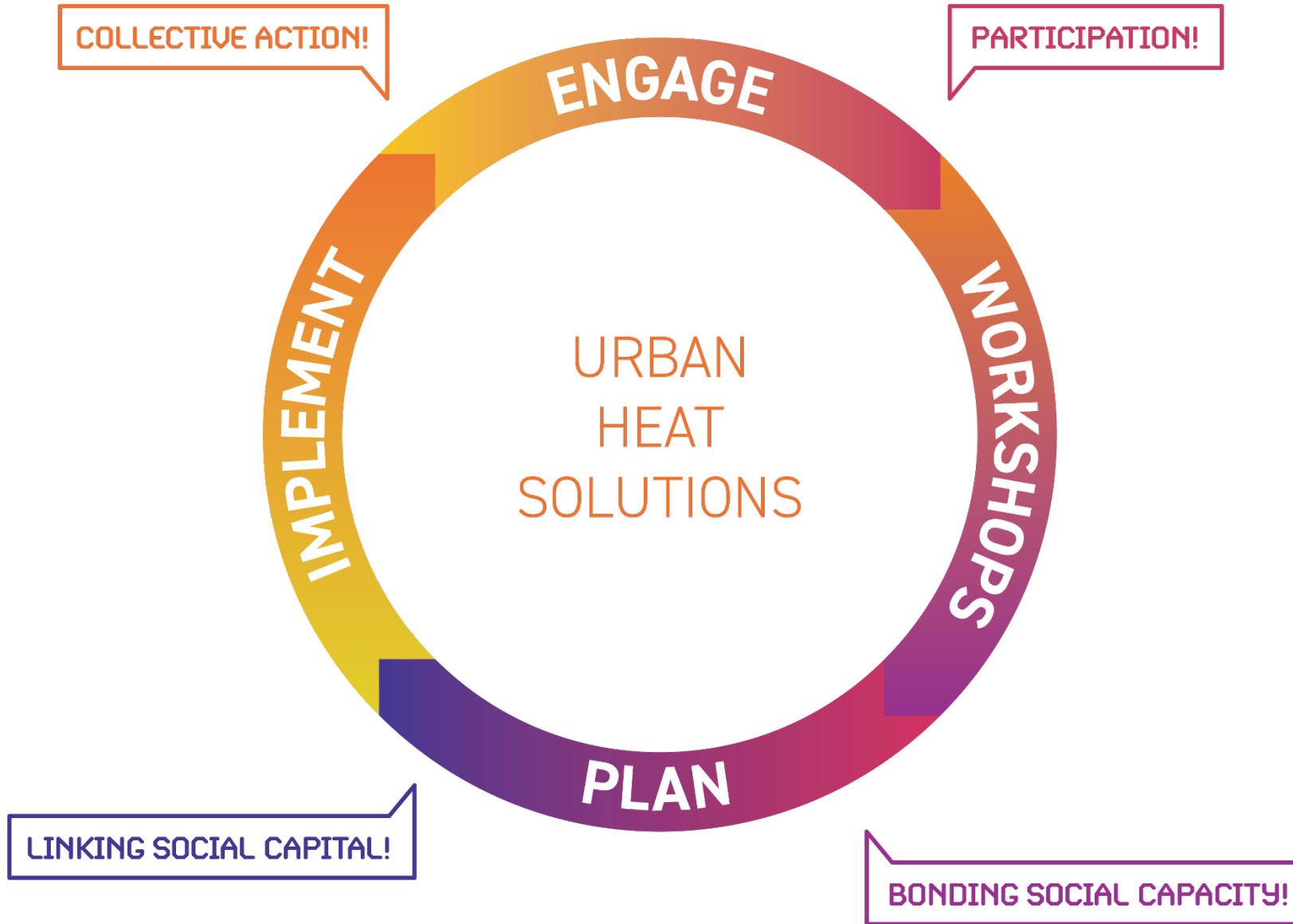


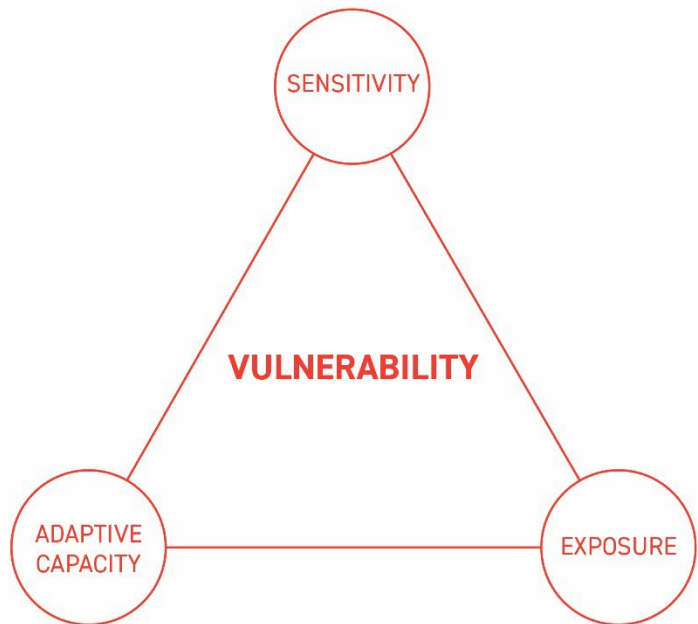
## TURN DOWN THE HEAT

STRATEGY AND  
ACTION PLAN

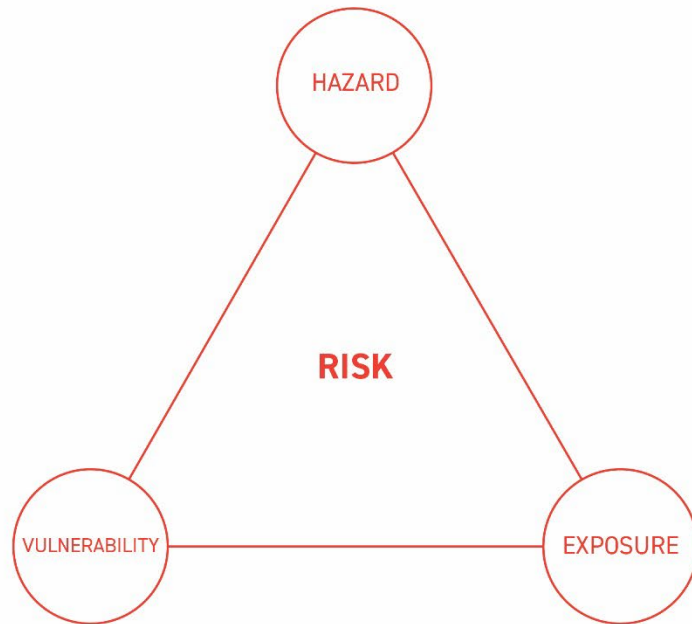
2018



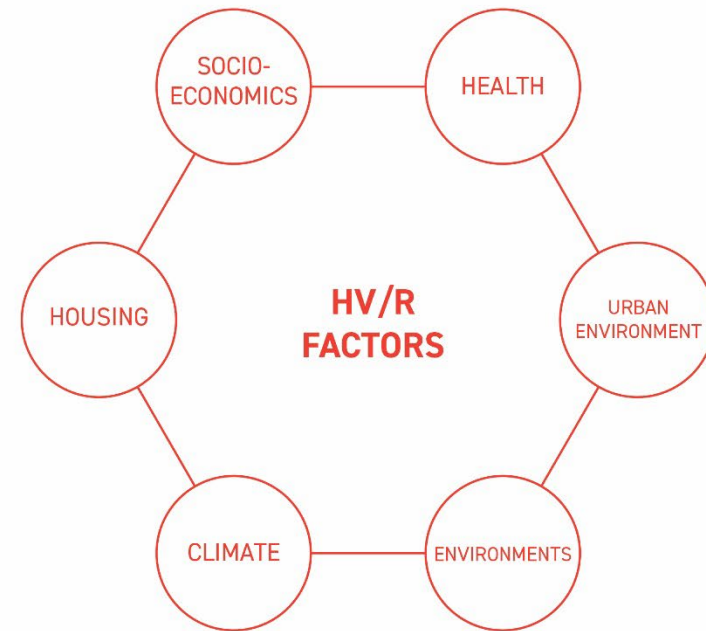




Cutter et al., 2003; Change, I. P. O. C., 2001



Crichton, 1999; Field and Barros, 2014



Cheng et. al., 2021





American Planning Association

*Creating Great Communities for All*

PAS REPORT 600

# PLANNING FOR URBAN HEAT RESILIENCE

Ladd Keith, PHD, and Sara Meerow, PHD

One Billion People More Resilient

# Heat Action Platform

LEARNING MODULES ▾

DOWNLOADS

POLICY TOOL

ABOUT ▾

LANGUAGE ▾



WELCOME

# Welcome to the Heat Action Platform

Use the Heat Action modules to assess, plan, implement and evaluate heat resilience project and programs that are appropriate for your context. Or, try the [Policy Tool](#).

START LEARNING MODULES



WELCOME




HOW TO USE

NEW RESOURCES

NEED MORE HELP?



## Assess

-  **Baseline Assessment**
-  **Identify Vulnerable Communities**
-  **Assess Awareness**

## Plan

 **Develop an Education Strategy**




 **Explore Adaptation Solutions**

 **Fund and Finance Projects**





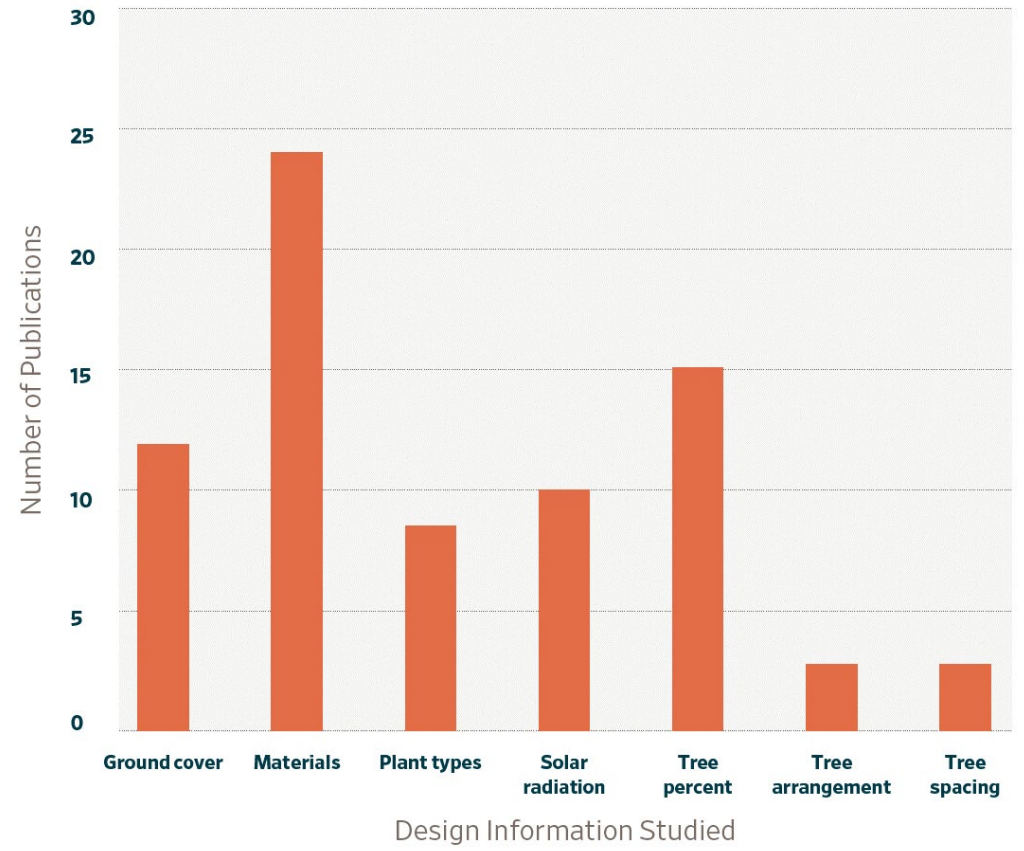
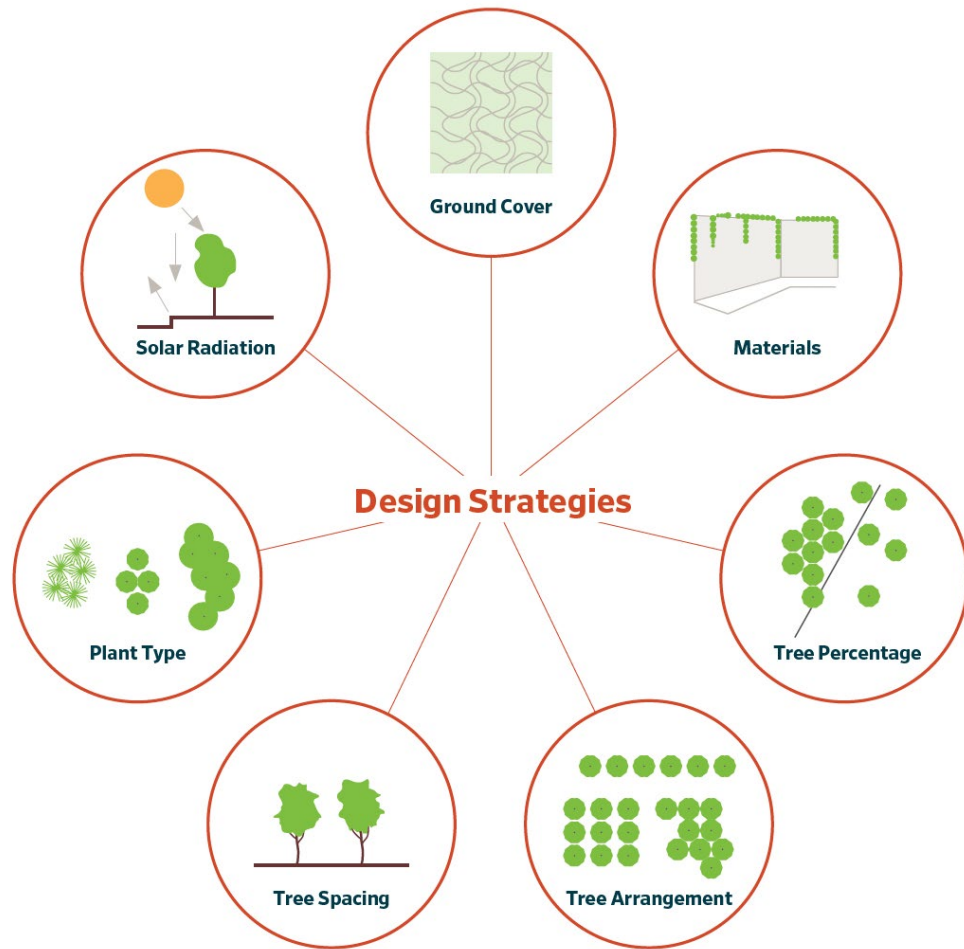
## Implement

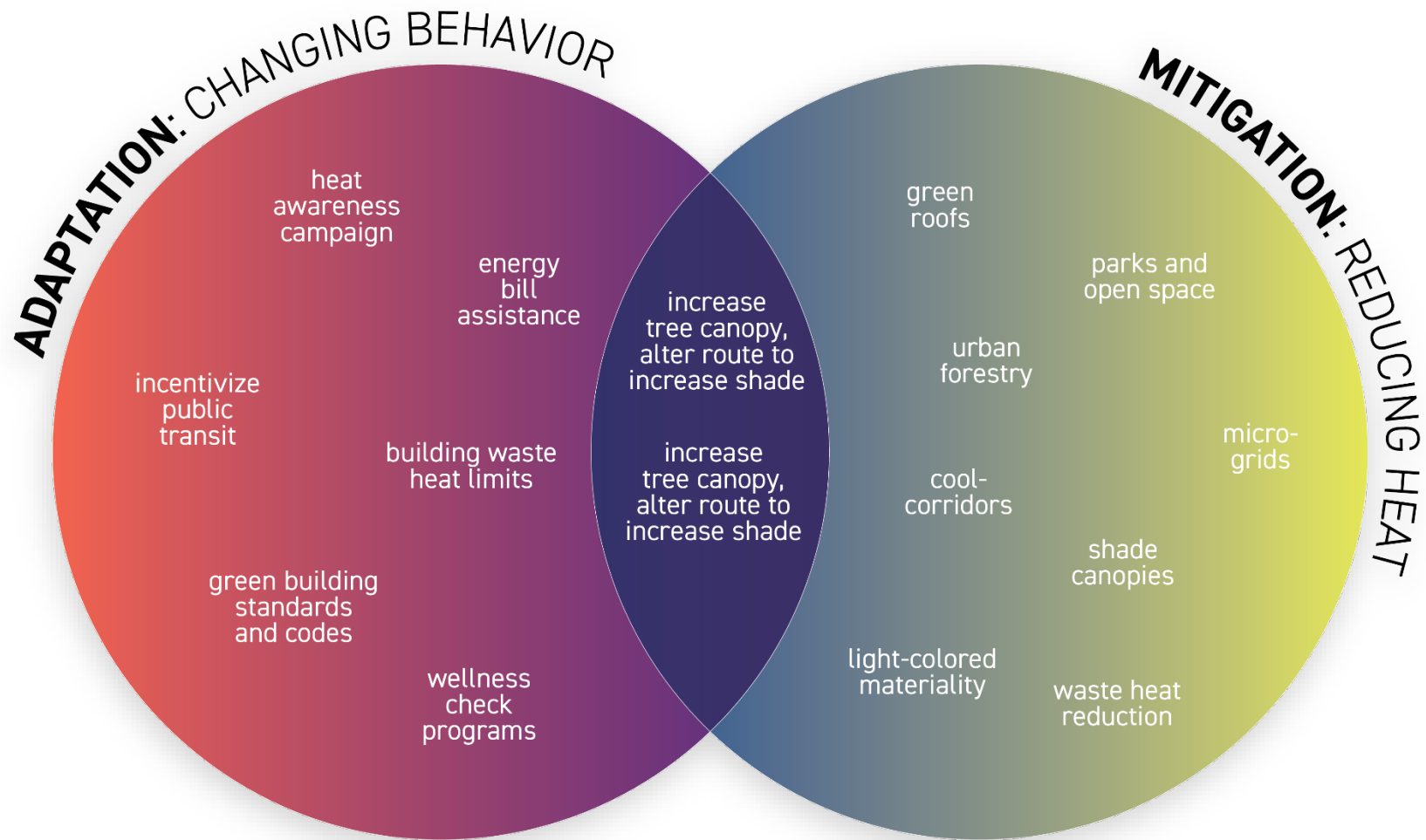
-  **Create a Heat Action Plan**
-  **Implement and Scale**
-  **Monitor and Evaluate**

02

# ADAPTATION AND MITIGATION TACTICS

- A Solutions to Extreme Heat
- B Adaptation
- C Mitigation







## ADAPTATION

<b>COMMUNITY</b>	Energy bill assistance
	Establishing urban forestry, tree, and landscape program
	Heat awareness campaign
	Providing incentives and awards
	Thermal comfort policies
<b>EMERGENCY</b>	Chief heat officers
	Cool hospital preparedness mandate
	Heat emergency response plan
	Heat hotlines
	Public transit services during heat waves
	Wellness check programs
<b>INFRASTRUCTURE</b>	Building materials and standards
	Building waste heat limits
	Green building and energy efficiency standards and codes
	Heat design guidelines
<b>ASSESSMENT</b>	Building energy benchmarking
	Catastrophe (CAT) bond
	Conduct a heat vulnerability assessment
	Design a heat management plan
	Heat-resilient environmental impact assessments

## MITIGATION

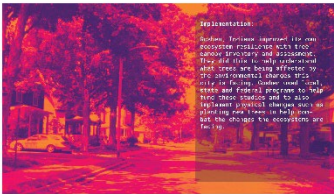
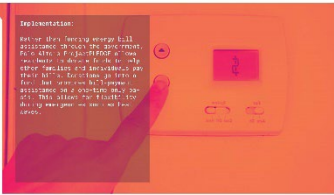
<b>MATERIAL</b>	Shade structures
	Permeable pavement
	Heat resilient building envelopes
	Light pavement/material
<b>ARCHITECTURE</b>	Cool roofs/walls
	Building orientation
	Exterior building shade
	Green building
<b>GREEN INFRASTRUCTURE</b>	Urban forestry
	Tree protection
	Parks and open space
	Water features
	Community gardens
	Green roofs
<b>ENERGY</b>	Cool corridors
	Microgrids
	Electric vehicle infrastructure
	District cooling
	Waste heat reduction
	Solar panels

### Energy Bill Assistance

**Description:** Many low-income households struggle to pay their utility bills. The City of Los Angeles provides assistance through the Los Angeles Energy Bill Assistance Program. This program helps eligible households pay their utility bills by providing a loan or a grant. The program is available to households with annual income below \$10,000. The program is available to households with annual income below \$10,000. The program is available to households with annual income below \$10,000.

**Impact:** The program helps households pay their utility bills, reducing the risk of utility shutoff. The program is available to households with annual income below \$10,000. The program is available to households with annual income below \$10,000. The program is available to households with annual income below \$10,000.

**Benefits:** The program helps households pay their utility bills, reducing the risk of utility shutoff. The program is available to households with annual income below \$10,000. The program is available to households with annual income below \$10,000. The program is available to households with annual income below \$10,000.



### Establishing Urban-Forest Programs

**Description:** Urban forests provide many benefits, including reducing air pollution, improving water quality, and providing shade. The City of Los Angeles has established an Urban-Forest Program to encourage the establishment and maintenance of urban forests. The program provides technical assistance and funding to help households establish and maintain urban forests.

**Impact:** The program helps households establish and maintain urban forests, improving air quality and water quality. The program is available to households with annual income below \$10,000. The program is available to households with annual income below \$10,000. The program is available to households with annual income below \$10,000.

**Benefits:** The program helps households establish and maintain urban forests, improving air quality and water quality. The program is available to households with annual income below \$10,000. The program is available to households with annual income below \$10,000. The program is available to households with annual income below \$10,000.

### Cool Hospital Preparedness Mandate

**Description:** The City of Los Angeles has established a Cool Hospital Preparedness Mandate to ensure that hospitals are prepared for heat emergencies. The mandate requires hospitals to develop and implement a heat emergency response plan. The plan must include measures to protect vulnerable populations, such as the elderly and the homeless.

**Impact:** The mandate ensures that hospitals are prepared for heat emergencies, protecting vulnerable populations. The mandate is available to all hospitals in the City of Los Angeles. The mandate is available to all hospitals in the City of Los Angeles. The mandate is available to all hospitals in the City of Los Angeles.

**Benefits:** The mandate ensures that hospitals are prepared for heat emergencies, protecting vulnerable populations. The mandate is available to all hospitals in the City of Los Angeles. The mandate is available to all hospitals in the City of Los Angeles. The mandate is available to all hospitals in the City of Los Angeles.



### Heat Emergency Response Plan

**Description:** A heat emergency response plan is a document that outlines the steps that a household should take in the event of a heat emergency. The plan should include measures to protect vulnerable populations, such as the elderly and the homeless. The plan should also include measures to protect the household's property.

**Impact:** A heat emergency response plan helps households prepare for heat emergencies, protecting vulnerable populations and property. The plan is available to all households in the City of Los Angeles. The plan is available to all households in the City of Los Angeles. The plan is available to all households in the City of Los Angeles.

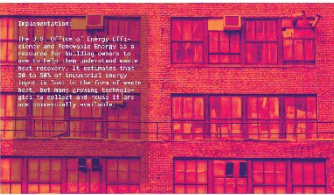
**Benefits:** A heat emergency response plan helps households prepare for heat emergencies, protecting vulnerable populations and property. The plan is available to all households in the City of Los Angeles. The plan is available to all households in the City of Los Angeles. The plan is available to all households in the City of Los Angeles.

### Building Waste Heat Limits

**Description:** Building waste heat is a byproduct of many building systems, such as air conditioning and heating. The City of Los Angeles has established a Building Waste Heat Limits program to reduce the amount of waste heat that buildings emit. The program requires buildings to install heat recovery systems that capture and reuse waste heat.

**Impact:** The program helps buildings reduce their waste heat emissions, improving energy efficiency and reducing greenhouse gas emissions. The program is available to all buildings in the City of Los Angeles. The program is available to all buildings in the City of Los Angeles. The program is available to all buildings in the City of Los Angeles.

**Benefits:** The program helps buildings reduce their waste heat emissions, improving energy efficiency and reducing greenhouse gas emissions. The program is available to all buildings in the City of Los Angeles. The program is available to all buildings in the City of Los Angeles. The program is available to all buildings in the City of Los Angeles.



### Green Building Standards & Codes

**Description:** Green building standards and codes are a set of guidelines that help building professionals design and construct buildings that are more energy efficient and environmentally friendly. The City of Los Angeles has established a Green Building Standards & Codes program to encourage the adoption of green building standards and codes.

**Impact:** The program helps building professionals design and construct buildings that are more energy efficient and environmentally friendly. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.

**Benefits:** The program helps building professionals design and construct buildings that are more energy efficient and environmentally friendly. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.

### Heat Awareness Campaign

**Description:** A heat awareness campaign is a public information campaign that educates the public about the risks of heat and how to protect themselves. The City of Los Angeles has established a Heat Awareness Campaign to educate the public about the risks of heat and how to protect themselves.

**Impact:** The campaign helps the public understand the risks of heat and how to protect themselves. The campaign is available to all households in the City of Los Angeles. The campaign is available to all households in the City of Los Angeles. The campaign is available to all households in the City of Los Angeles.

**Benefits:** The campaign helps the public understand the risks of heat and how to protect themselves. The campaign is available to all households in the City of Los Angeles. The campaign is available to all households in the City of Los Angeles. The campaign is available to all households in the City of Los Angeles.



### Providing Incentives and Awards

**Description:** Incentives and awards are a way to encourage households to take steps to reduce their energy consumption. The City of Los Angeles has established a program to provide incentives and awards to households that take steps to reduce their energy consumption.

**Impact:** The program helps households take steps to reduce their energy consumption, improving energy efficiency and reducing greenhouse gas emissions. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles.

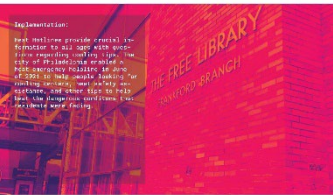
**Benefits:** The program helps households take steps to reduce their energy consumption, improving energy efficiency and reducing greenhouse gas emissions. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles.

### Heat Hotlines

**Description:** A heat hotline is a phone number that households can call for help with heat-related problems. The City of Los Angeles has established a Heat Hotline to provide help to households with heat-related problems.

**Impact:** The hotline helps households with heat-related problems, improving their safety and comfort. The hotline is available to all households in the City of Los Angeles. The hotline is available to all households in the City of Los Angeles. The hotline is available to all households in the City of Los Angeles.

**Benefits:** The hotline helps households with heat-related problems, improving their safety and comfort. The hotline is available to all households in the City of Los Angeles. The hotline is available to all households in the City of Los Angeles. The hotline is available to all households in the City of Los Angeles.



### Public Transit During Heat Waves

**Description:** Public transit is a safe and comfortable way to get around during heat waves. The City of Los Angeles has established a program to provide public transit during heat waves.

**Impact:** The program helps households with heat-related problems, improving their safety and comfort. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles.

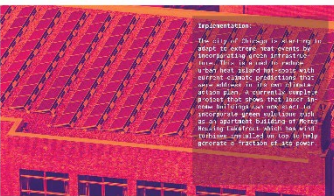
**Benefits:** The program helps households with heat-related problems, improving their safety and comfort. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles.

### Heat Design Guidelines

**Description:** Heat design guidelines are a set of guidelines that help building professionals design buildings that are more energy efficient and environmentally friendly. The City of Los Angeles has established a Heat Design Guidelines program to encourage the adoption of heat design guidelines.

**Impact:** The program helps building professionals design buildings that are more energy efficient and environmentally friendly. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.

**Benefits:** The program helps building professionals design buildings that are more energy efficient and environmentally friendly. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.



### Building Energy Benchmarking

**Description:** Building energy benchmarking is a process of comparing a building's energy consumption to other buildings of similar size and type. The City of Los Angeles has established a Building Energy Benchmarking program to encourage the adoption of building energy benchmarking.

**Impact:** The program helps building professionals understand their building's energy consumption and how to improve it. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.

**Benefits:** The program helps building professionals understand their building's energy consumption and how to improve it. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.

### Thermal Comfort Policies

**Description:** Thermal comfort policies are a set of guidelines that help building professionals design buildings that are more comfortable and energy efficient. The City of Los Angeles has established a Thermal Comfort Policies program to encourage the adoption of thermal comfort policies.

**Impact:** The program helps building professionals design buildings that are more comfortable and energy efficient. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.

**Benefits:** The program helps building professionals design buildings that are more comfortable and energy efficient. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.



### Chief Heat Officer

**Description:** A Chief Heat Officer is a position that is responsible for coordinating the City of Los Angeles' response to heat emergencies. The City of Los Angeles has established a Chief Heat Officer position to coordinate the City's response to heat emergencies.

**Impact:** The Chief Heat Officer helps coordinate the City's response to heat emergencies, improving the City's preparedness. The Chief Heat Officer is available to all households in the City of Los Angeles. The Chief Heat Officer is available to all households in the City of Los Angeles. The Chief Heat Officer is available to all households in the City of Los Angeles.

**Benefits:** The Chief Heat Officer helps coordinate the City's response to heat emergencies, improving the City's preparedness. The Chief Heat Officer is available to all households in the City of Los Angeles. The Chief Heat Officer is available to all households in the City of Los Angeles. The Chief Heat Officer is available to all households in the City of Los Angeles.

### Wellness Check Programs

**Description:** A wellness check program is a program that provides health and safety checks to households that are at risk of heat-related problems. The City of Los Angeles has established a Wellness Check Program to provide health and safety checks to households that are at risk of heat-related problems.

**Impact:** The program helps households that are at risk of heat-related problems, improving their safety and health. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles.

**Benefits:** The program helps households that are at risk of heat-related problems, improving their safety and health. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles.



### Building Material Standards

**Description:** Building material standards are a set of guidelines that help building professionals select materials that are more energy efficient and environmentally friendly. The City of Los Angeles has established a Building Material Standards program to encourage the adoption of building material standards.

**Impact:** The program helps building professionals select materials that are more energy efficient and environmentally friendly. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.

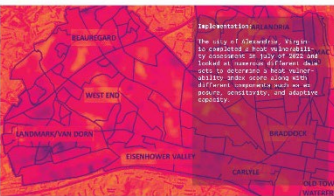
**Benefits:** The program helps building professionals select materials that are more energy efficient and environmentally friendly. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.

### Catastrophe (CAT) Bonds

**Description:** Catastrophe (CAT) bonds are a type of insurance that helps building professionals protect their buildings from natural disasters. The City of Los Angeles has established a Catastrophe (CAT) Bonds program to encourage the adoption of catastrophe (CAT) bonds.

**Impact:** The program helps building professionals protect their buildings from natural disasters, improving their safety and security. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.

**Benefits:** The program helps building professionals protect their buildings from natural disasters, improving their safety and security. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles. The program is available to all building professionals in the City of Los Angeles.



### Conduct a Heat Vulnerability Assessment

**Description:** A heat vulnerability assessment is a process of identifying households that are most vulnerable to heat-related problems. The City of Los Angeles has established a Heat Vulnerability Assessment program to identify households that are most vulnerable to heat-related problems.

**Impact:** The program helps identify households that are most vulnerable to heat-related problems, improving their safety and health. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles.

**Benefits:** The program helps identify households that are most vulnerable to heat-related problems, improving their safety and health. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles. The program is available to all households in the City of Los Angeles.

## Community Gardens

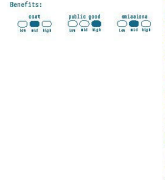
**Description:** Vacant, non-vegetated land parcels can be converted to green spaces that provide social, economic, and environmental benefits. In addition to aesthetic benefits, gardens can provide food, improve air quality, and provide shade. Community gardens provide fresh produce for their members, improve air quality, and provide shade.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Green Roofs

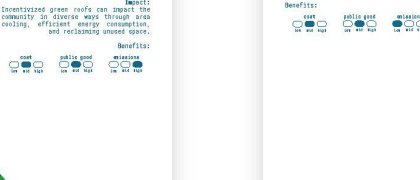
**Description:** Green roofs cool the surrounding air and can also serve as additional green space. There are two main types of green roofs: intensive and extensive. Intensive green roofs support vegetation and can be used as a garden. Extensive green roofs support low-growing plants and require less maintenance.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Electric Vehicle Infrastructure

**Description:** Electric vehicle infrastructure includes charging stations and power distribution systems. It is essential for the widespread adoption of electric vehicles.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Microgrids

**Description:** Microgrids are small-scale power grids that can operate independently or in conjunction with the main grid. They provide a reliable and renewable source of energy.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Cool roofs & walls

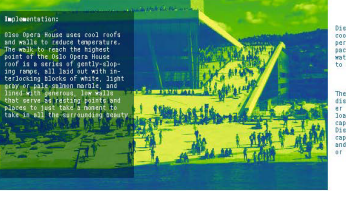
**Description:** Cool roofs and walls use reflective materials to reduce heat absorption. They help lower building temperatures and reduce energy consumption.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## District cooling

**Description:** District cooling involves a central plant that provides cooling for multiple buildings. It is more efficient than individual building cooling systems.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Parks and Open Space

**Description:** Parks and open spaces provide recreational opportunities and improve air quality. They also provide shade and reduce urban heat island effect.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Tree Protection

**Description:** Tree protection involves preserving existing trees and planting new ones. Trees provide shade, improve air quality, and reduce urban heat island effect.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Walkability and Cool Corridors

**Description:** Walkability and cool corridors involve creating pedestrian-friendly paths and green spaces. They improve air quality and reduce urban heat island effect.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Waste Heat Reduction

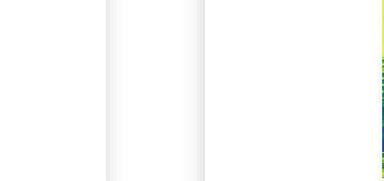
**Description:** Waste heat reduction involves capturing and utilizing heat that is otherwise lost. It can improve energy efficiency and reduce greenhouse gas emissions.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Exterior building shade

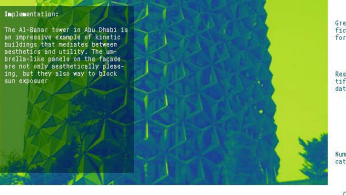
**Description:** Exterior building shade involves creating shade structures that reduce heat absorption and improve energy efficiency.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Green building

**Description:** Green building involves designing and constructing buildings that are environmentally friendly and energy-efficient.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Urban Forestry

**Description:** Urban forestry involves planting and maintaining trees in urban areas. Trees provide shade, improve air quality, and reduce urban heat island effect.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Public Water Features

**Description:** Public water features include fountains, water walls, and water gardens. They provide shade, improve air quality, and reduce urban heat island effect.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Building envelopes

**Description:** Building envelopes involve improving the insulation and airtightness of buildings to reduce energy consumption.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Building orientation

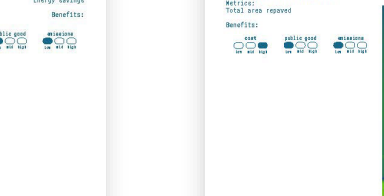
**Description:** Building orientation involves designing buildings to maximize natural light and ventilation while minimizing heat gain.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Light-colored material

**Description:** Light-colored materials reflect heat and reduce heat absorption. They help lower building temperatures and reduce energy consumption.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.



## Permeable pavement

**Description:** Permeable pavement allows water to infiltrate the ground, reducing runoff and improving air quality. It also helps reduce urban heat island effect.

**Target Beneficiaries:** Property owners, residents, and businesses.

**Phase of Impact:** Planning and design.

**Metrics:** Risk reduction and mitigation.

**Energy Savings:** Decrease in energy consumption.





IMAGE CREDIT: Carolina A. Miranda / Los Angeles Times



# Short on Shade

Research on Equity and  
Exposure in Los Angeles

swa

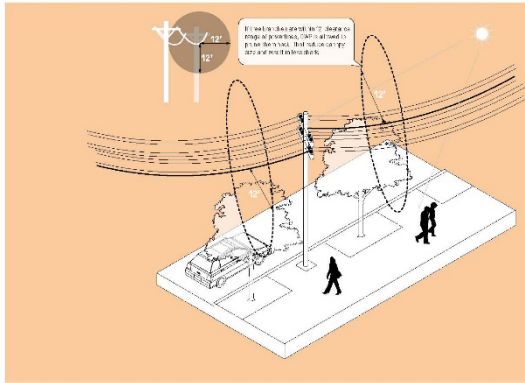
01

Utility Clearance

California State's standard for clearance around power lines has increased from 4 feet to 12 feet since 2017.

POLICY AND CODE

State of California  
California Public Utilities Commission  
Order 96, Rules 39, Table 1  
Class 4 for High Voltage Areas



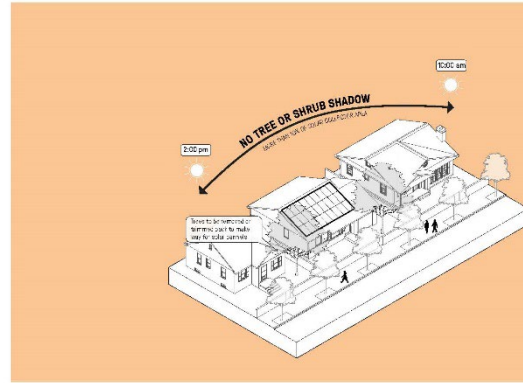
02

Solar Rights

Solar Shade Control Act: Trees, shrubs or other shade forms give way to solar collectors.

POLICY AND CODE

State of California  
California Public Resources Code  
Division 15, Chapter 10: Solar Shade Control  
(28261 - 28269)



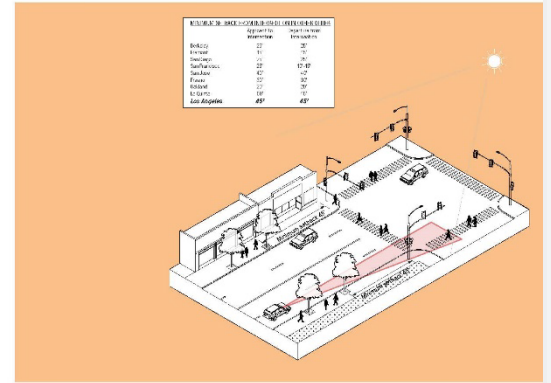
03

Intersection Setbacks

City guidelines require a 45-foot setback from intersections for tree planting.

POLICY AND CODE

State of California  
Tree Seeding Ordinance  
Bureau of Street Services  
City of Los Angeles



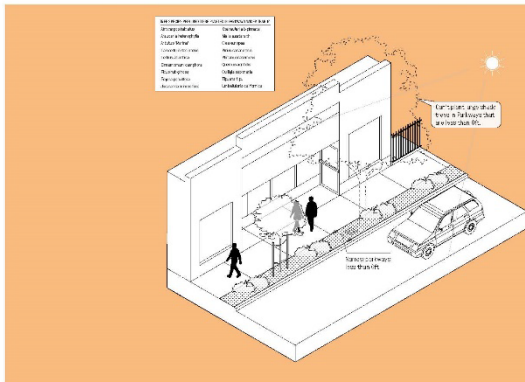
04

Narrow "Hellstrips"

The City prohibits planting of large trees in parkways less than 8 feet wide in order to protect sidewalks and underground utilities.

POLICY AND CODE

City of Los Angeles  
Approved Street Tree List  
City of Los Angeles



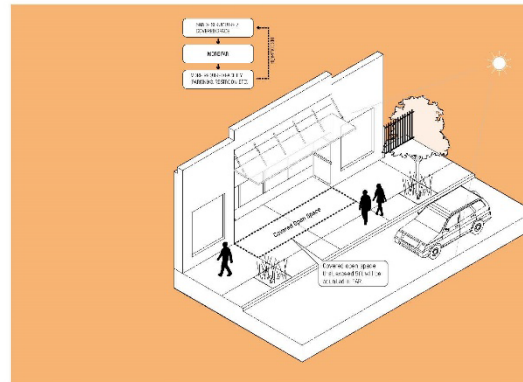
05

Floor Area Ratio

Covered open space that exceeds 5 feet, or that is supported by columns, is counted as floor space in FAR code, discouraging developers from building shade structures in the public realm.

POLICY AND CODE

City of Los Angeles  
Los Angeles Municipal Code  
Section 12.00: Signage Protection  
for Height and Foot Area  
City of Los Angeles



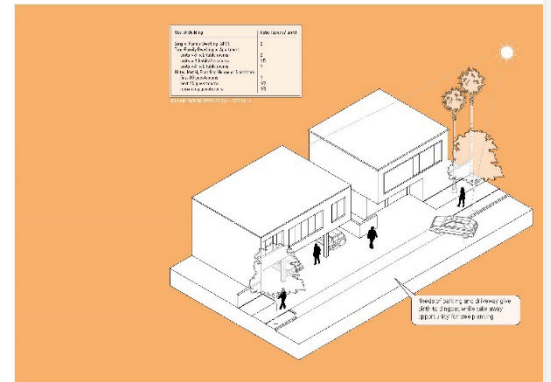
06

Parking Requirements

Diaghats, a housing type that originating in a car-centric era, provide generous parking space but limit planting areas. Parking and driveway needs supersede opportunities for tree shade.

POLICY AND CODE

City of Los Angeles

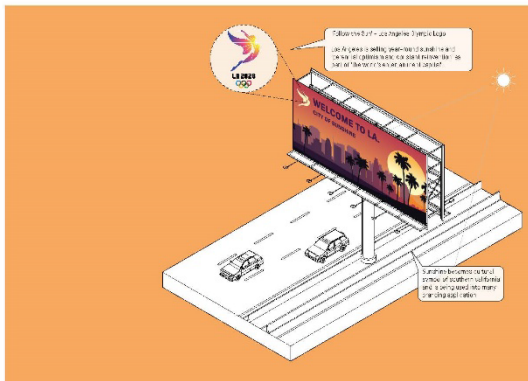


07

### Sun Symbolism

Sunshine is culturally prized by Los Angeles as a symbol of their city. Angelenos' attitude towards sunshine complicates the provision of shade.

CULTURAL IDENTITY  
City of Los Angeles



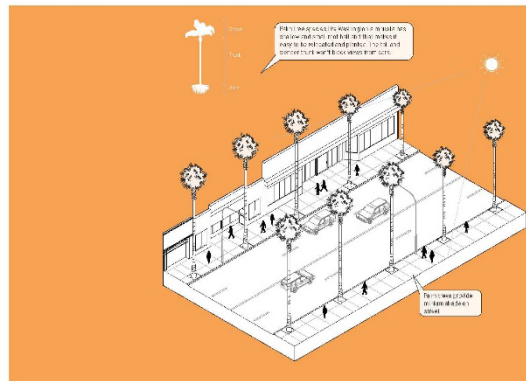
08

### Palms Mean Paradise

Palm trees became one of the dominant Los Angeles street tree species, due in part to characteristics that were ideal for an area dominated by cars.

The ubiquity of these trees has resulted in less overall street shade.

CULTURAL IDENTITY  
City of Los Angeles

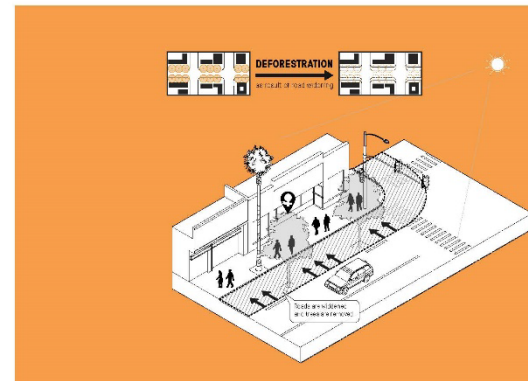


09

### Cars Trump Trees

Car-oriented road-widening development practices resulted in diminished parkways that are not wide enough for shade trees.

CAR-CENTRIC URBANISM  
City of Los Angeles



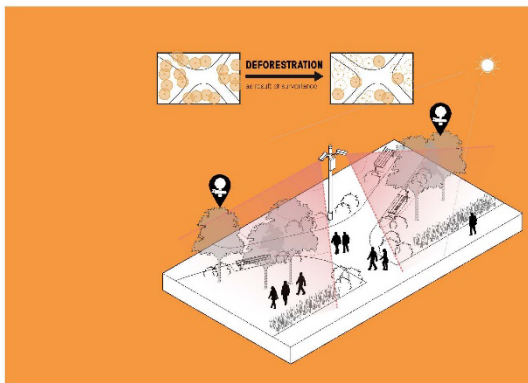
10

### Policing and Surveillance

Shade is considered as an impediment to surveillance and safety, resulting in a preference for unshaded public space by law enforcement agencies. Sunlight was weaponized to deter "deviants and criminals" in Los Angeles.

#### SHADE STEWARDSHIP

City of Los Angeles  
In 1904, business owners agreed on a redesign method to clear out "deviants and criminals." The City removed palm trees, benches and shaded alleys trees and even palms so that office workers and shoppers could move through the city without being "hounded by deviants and thugs." Sunlight was purposely weaponized with the intent that "thugs, loafers, and others" could see walking through "nooks of crooked, Paris'ing squares."  
—Sun "Blows 'Shades,' Palms Journal, April 20/9, (accessed 11 Dec. 2013)



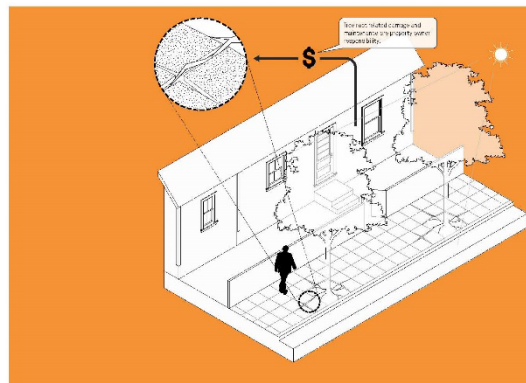
11

### Tree Maintenance

Adjacent owners are responsible for the maintenance of parkway trees, resulting in their becoming a private financial burden.

Tree watering and maintenance were historically the obligation of property owners until 1932, when the City began to take more responsibility for managing street trees. However, root-related damage and maintenance remain property owners' responsibility today.

SHADE STEWARDSHIP  
City of Los Angeles



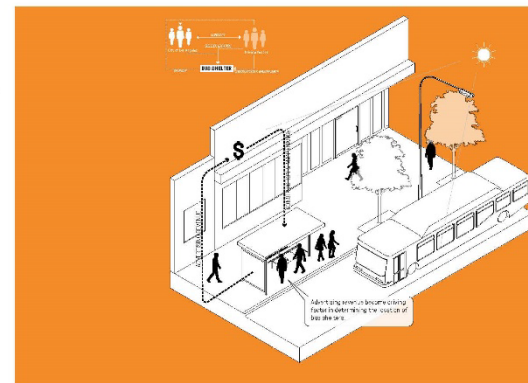
12

### Advertising Dollars

The City of Los Angeles signed contracts with private vendors to install and maintain bus shelters in exchange for advertising space on the shelters themselves.

Advertising revenue became a driving factor in determining bus shelter locations, with the result that "high-value" neighborhoods benefit from more bus shelter shade.

SHADE STEWARDSHIP  
City of Los Angeles





03

# METHODS FOR VISUALIZING HEAT

- A** Landsat/GIS
- B** UAV Infrared Thermography
- C** Handheld Thermography
- E** Mobile Biometeorological Instrument Platform
- F** Vehicle-Mounted Thermocouple Sensors
- G** Environmental Simulation
- H** Community-led Assessment

DRAFT!

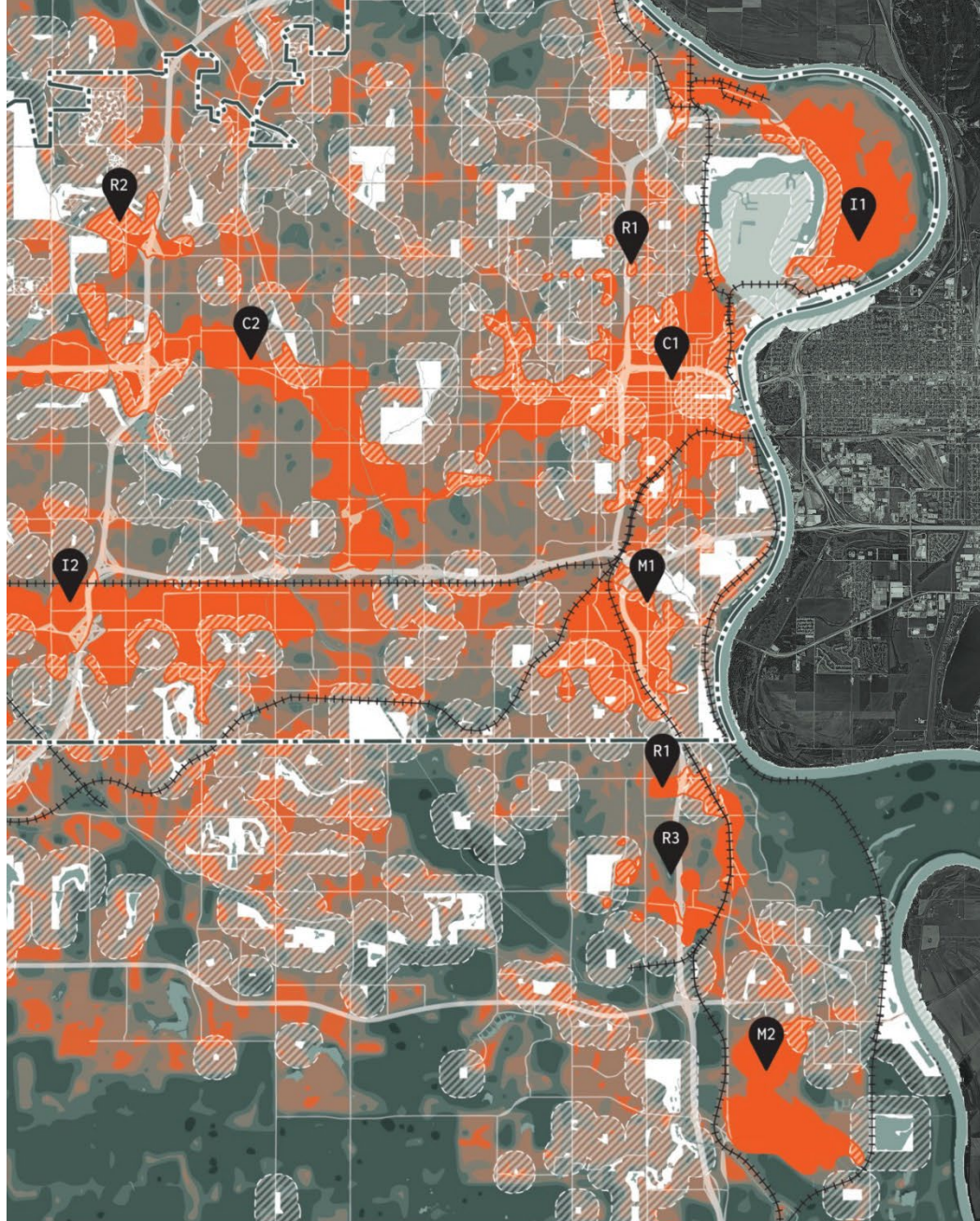
# THERMAL TOOLKIT

TECHNOLOGIES AND TECHNIQUES FOR VISUALIZING THERMAL DISPARITIES

A PROJECT OF THE LANDSCAPE ARCHITECTURE FOUNDATION DEB MITCHELL RESEARCH GRANT

- A Landsat/GIS
- B UAV Infrared Thermography
- C Handheld Thermography
- E Mobile Biometeorological Instrument Platform
- F Vehicle-Mounted Thermocouple Sensors
- G Environmental Simulation
- H Community-led Assessment

VISUALIZATION TOOL	DESCRIPTION	ASSESSMENT	TOOLS	SCALE			PROJECT PHASE		
				REGIONAL	NEIGHBORHOOD	SITE	PRE-DESIGN	DESIGN	POST-DESIGN
LANDSAT IMAGERY/GIS DATA	Satellite imagery used to map surface temperature and land cover.	Land surface temperature, Land cover classification	GIS software (e.g., ArcGIS, QGIS), Landsat imagery, Tree Equity Score (TES)	●	●		○		
UAV INFRARED THERMOGRAPHY	Use of drones equipped with infrared cameras to capture high-resolution thermal images.	Material surface temperature, infrared radiation (IR)	UAVs, infrared cameras (e.g., FLIR)		●	●	○		○
HANDHELD THERMOGRAPHY	Portable infrared cameras to measure temperature variations on the ground level.	Material surface temperature, infrared radiation (IR)	Handheld infrared cameras (e.g., FLIR)		●	●	○		○
MOBILE BIOMETEOROLOGICAL INSTRUMENT PLATFORM	Mobile units equipped with sensors to measure various environmental parameters that comprise mean radiant temperature.	Air temperature (°C), humidity (%), wind speed (m/s). Mean Radiant Temperature, 6-directional method for obtaining average temperature of all surfaces surrounding a person, including walls, floors, and objects.	Mobile meteorological stations (e.g. MaRTy)				●	○	
VEHICLE-MOUNTED THERMOCOUPLE SENSORS	Thermocouples mounted on vehicles to measure temperature while driving through different areas.	Air temperature	Vehicles, thermocouple sensors		●	●	○		
ENVIRONMENTAL SIMULATION (e.g. ENVI-met)	Simulation software to model and predict microclimatic conditions in urban environments.	Temperature (°C), wind flow (m/s), humidity (%)	ENVI-met software		●	●	○	○	
COMMUNITY ENGAGEMENT/HEAT WALKS	Engaging with the community to collect temperature data and identify heat-affected areas.	Perceived temperature, community feedback, qualitative data	Surveys, mobile apps, handheld thermometers		●	●	○	○	○



Heat Islands and proximity to green space in Omaha, NE. Landsat 8 and GIS data. Map by Salvador Lindquist.

#### SCALE/RESOLUTION

regional neighborhood site

#### PROJECT PHASE

pre-design design post-design

# LANDSAT / GIS

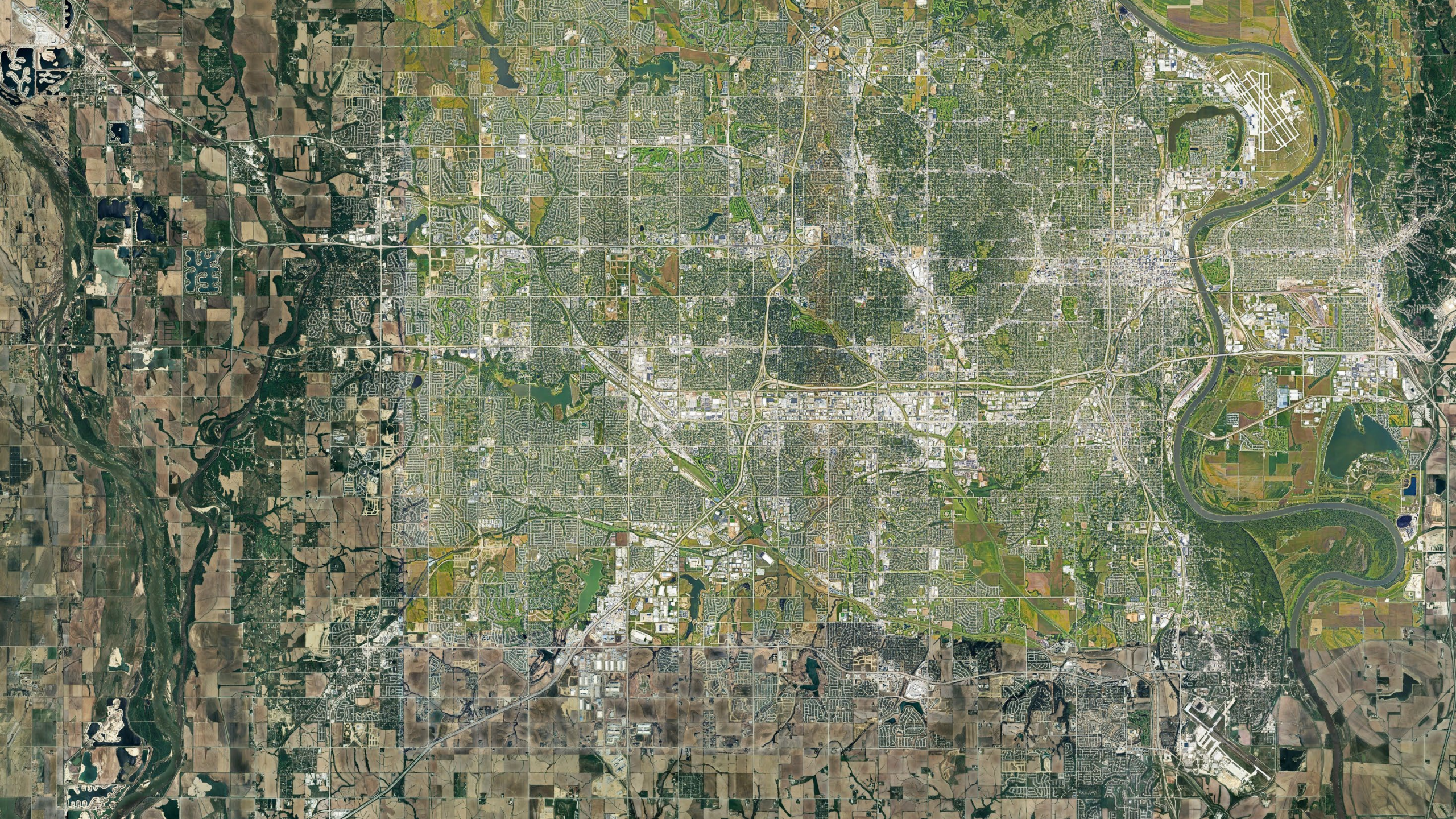
## BRIEF DESCRIPTION:

Landsat is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey (USGS). Launched initially in 1972, the Landsat program has provided a continuous record of Earth's surface, making it one of the longest-running satellite imagery programs in existence. The satellites are equipped with various sensors which capture data across multiple spectral bands, from visible light to thermal infrared. This diverse range of data allows for detailed analysis of land cover, vegetation health, and, crucially, surface temperature, making Landsat an invaluable tool for studying urban heat islands and other climate-related phenomena.
















Geographic Information Systems (GIS) coordinate with Landsat data to provide a powerful platform for analyzing and visualizing the spatial distribution of heat. By integrating the spectral data from Landsat with other geographical data layers, GIS enables researchers and urban planners to map temperature variations across different regions,

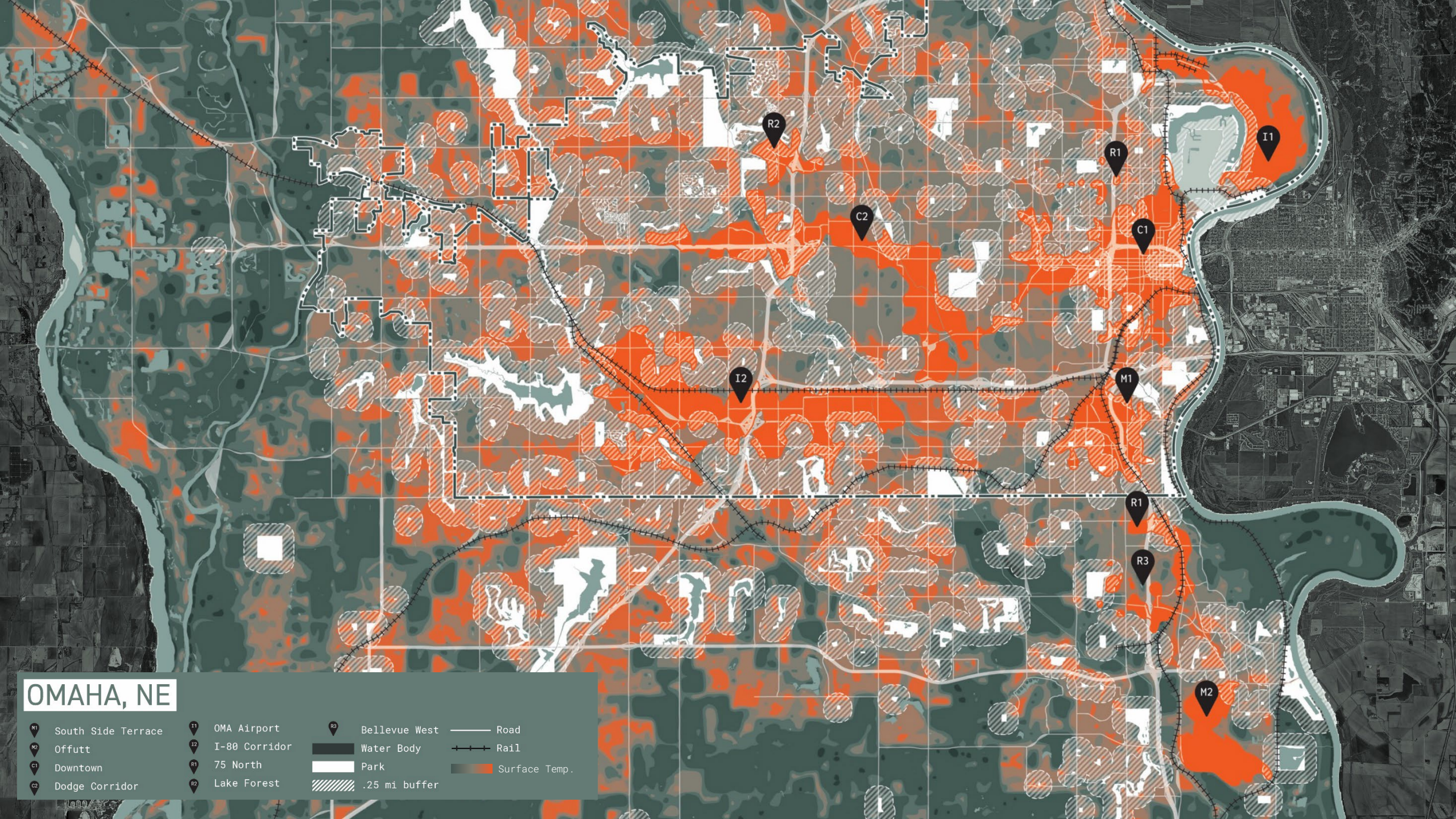
identify hotspots, and correlate these findings with factors such as land use, population density, and socioeconomic variables. For example, by overlaying temperature data with land cover maps, GIS can reveal how different surfaces (like concrete, vegetation, and water bodies) contribute to urban heat islands, offering insights into where mitigation efforts are most needed.

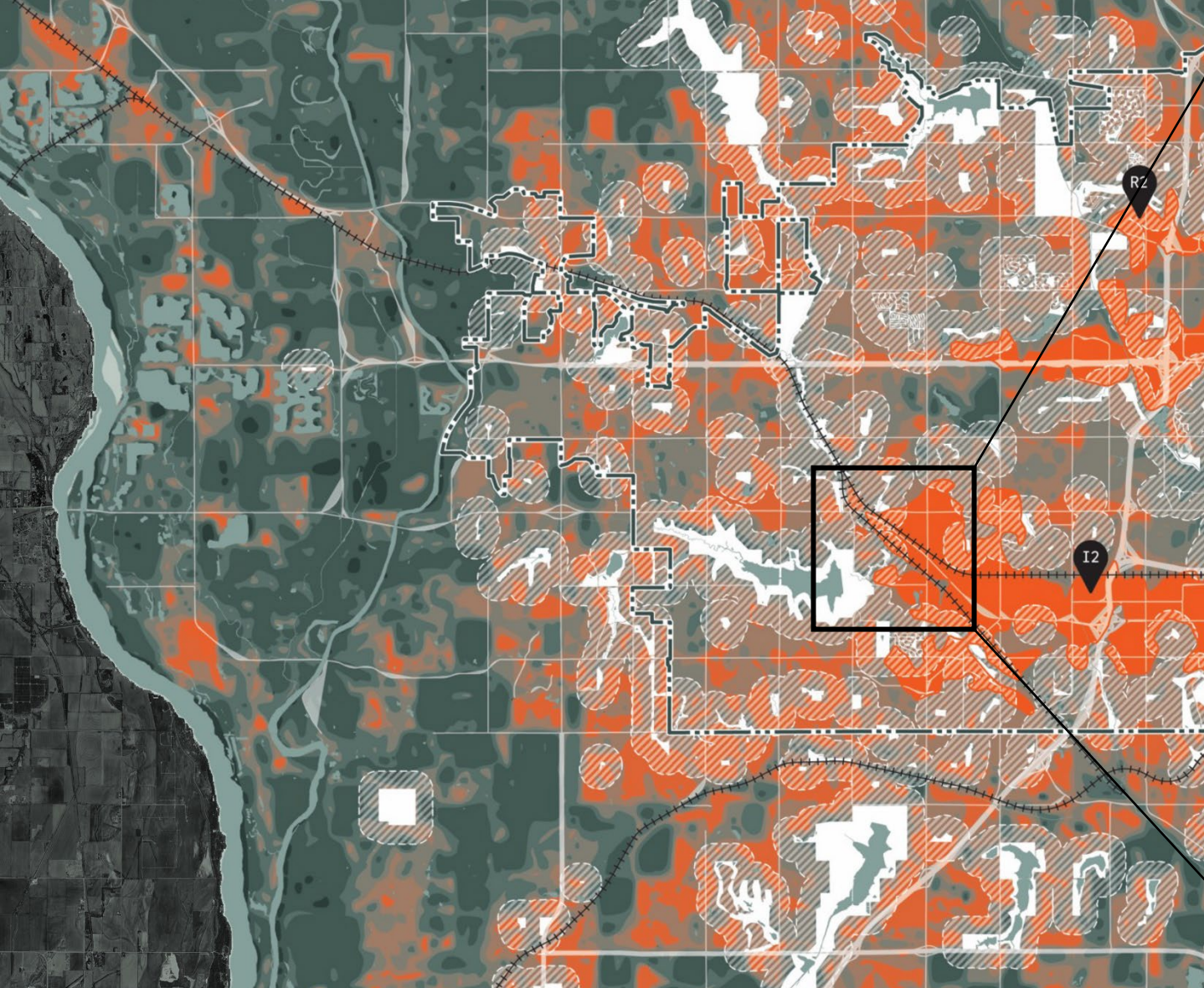
The applications of Landsat and GIS in understanding heat distribution are extensive. On a regional scale, these tools can be used to monitor changes in surface temperatures over time, helping to track the effectiveness of interventions like tree planting or reflective roofing. They also play a critical role in assessing the impact of urbanization on local climates, guiding policy decisions aimed at improving urban resilience to extreme heat. Additionally, by combining Landsat data with demographic information in GIS, planners can identify vulnerable communities disproportionately affected by heat, ensuring that adaptation and mitigation strategies are equitably distributed.



# OMAHA, NE

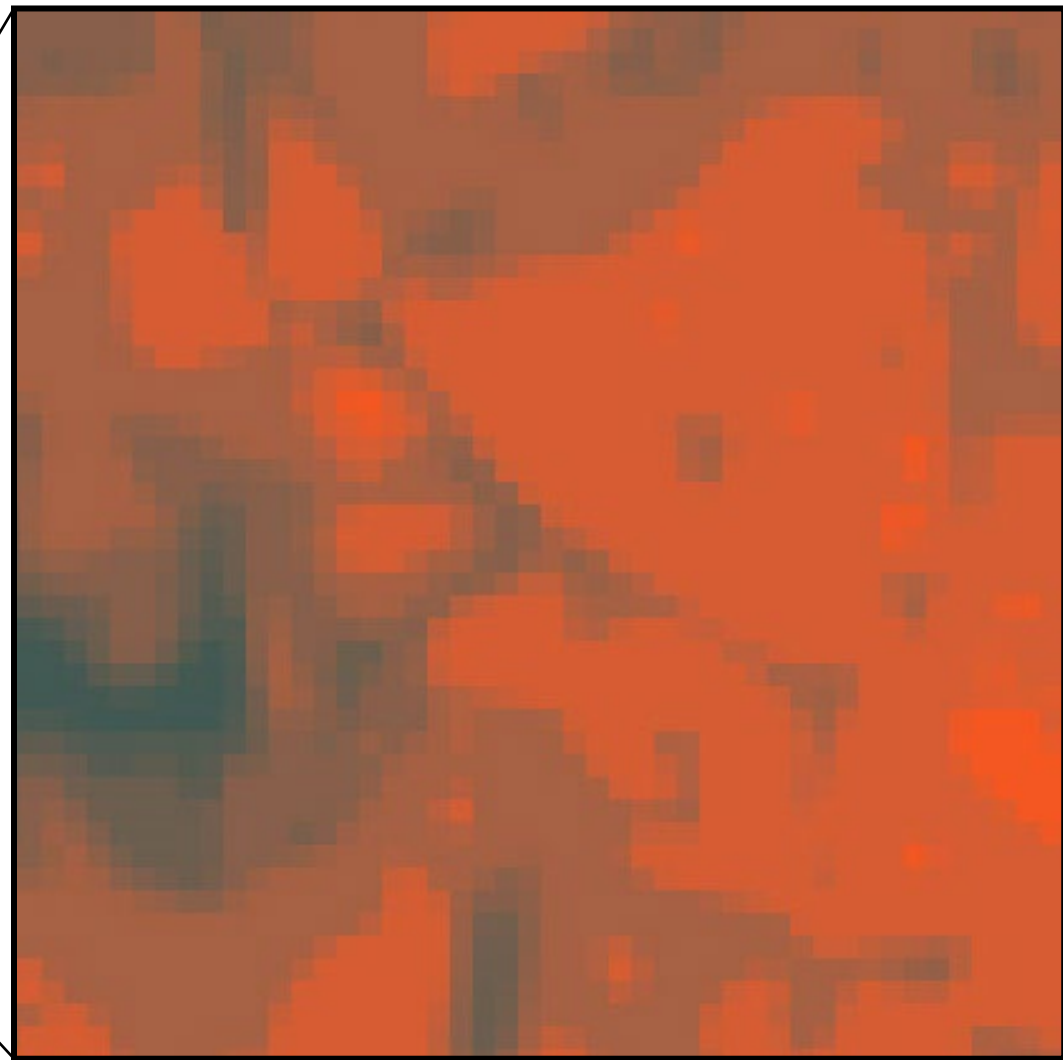
- |  |   |   |  |
|--|---|---|--|
|  South Side Terrace |  OMA Airport   |  Bellevue West |  Road           |
|  Offutt             |  I-80 Corridor |  Water Body    |  Rail           |
|  Downtown           |  75 North      |  Park          |  Surface Temp. |
|  Dodge Corridor     |  Lake Forest   |  .25 mi buffer |  |





## OMAHA, NE

- |                       |                  |                  |               |
|-----------------------|------------------|------------------|---------------|
| M1 South Side Terrace | T1 OMA Airport   | R3 Bellevue West | Road          |
| R2 Offutt             | I2 I-80 Corridor | Water Body       | Rail          |
| C1 Downtown           | R1 75 North      | Park             | Surface Temp. |
| C2 Dodge Corridor     | R2 Lake Forest   | .25 mi buffer    |               |



The U.S. Geological Survey (USGS) provides georeferenced Landsat surface temperature maps available at a 30m x 30m spatial resolution. These data work well at a large scale (county or state), but lack the fidelity and resolution required to make targeted site-based landscape interventions.



Abdoulaziz Abdoulaye of UNMC demonstrates a sensor used in the heat study (Photo by Fred Knapp, Nebraska Public Media News)



# VEHICLE-TRAVERSE COLLECTION

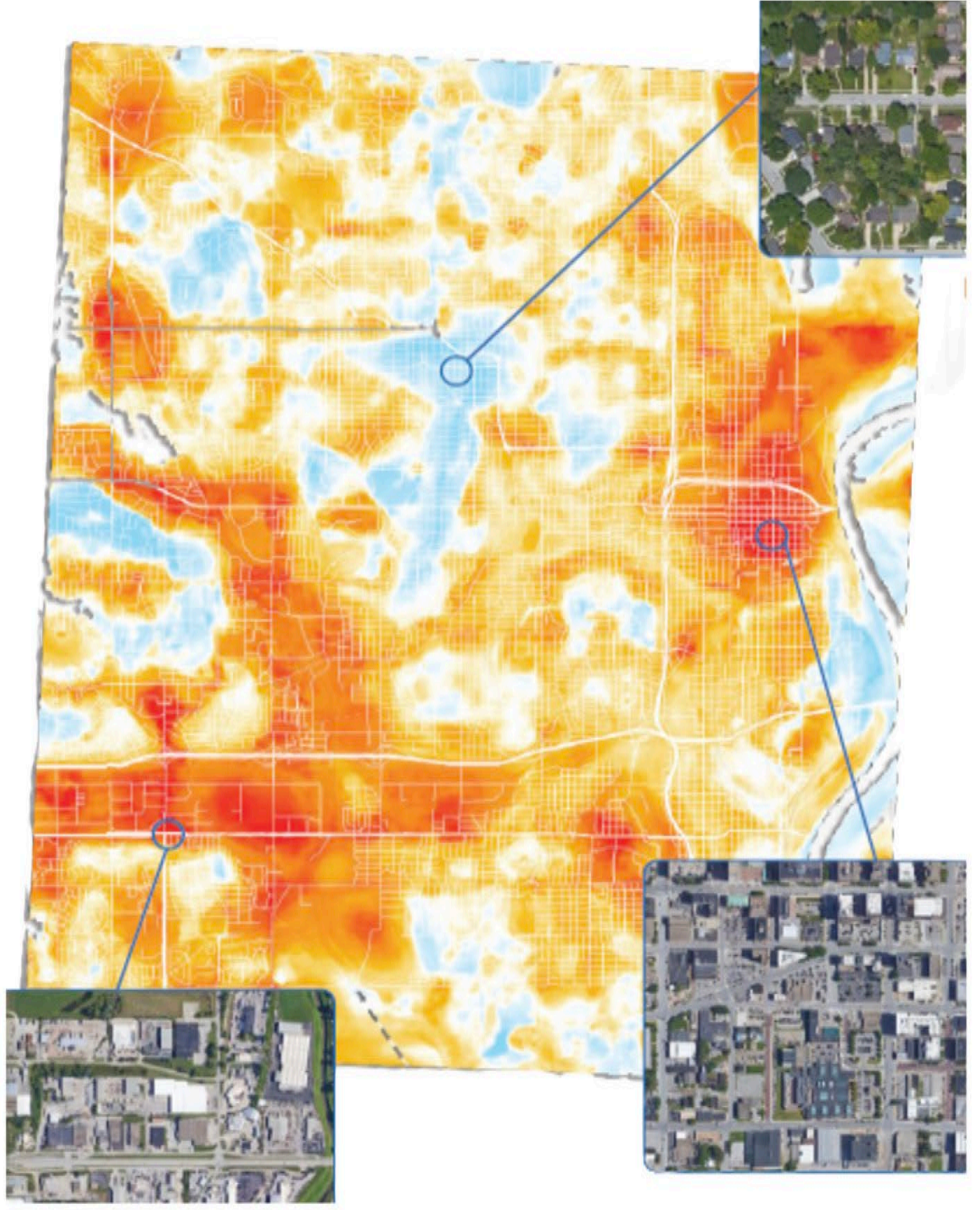
## BRIEF DESCRIPTION

Vehicle-traverse collection is a dynamic method used to assess the urban heat island (UHI) effect by equipping vehicles with thermal imaging technology to capture surface temperature data across different urban areas. This approach involves driving a vehicle fitted with thermal sensors, such as infrared cameras or temperature probes, which continuously record temperatures as the vehicle traverses various streets and neighborhoods.

This method provides a comprehensive, real-time view of temperature variations across a city, capturing data across a wide range of locations in a single trip. This continuous data collection enables detailed analysis of temperature gradients and hotspots over large areas, offering insights into how urban design, land use, and infrastructure contribute to the UHI effect. Unlike stationary measurements, which are limited to fixed points, vehicle-traverse collection can reveal varying street-level conditions and identify areas with significant heat disparities.

Vehicle-traverse collection stands out from other heat visualization methods such as UAV, handheld thermography, and Landsat imagery. While UAVs capture data from fixed altitudes and may miss ground-level variations, and handheld thermography provides localized measurements, vehicle-traverse collection combines the mobility of vehicles with high-resolution thermal sensing to cover extensive urban areas. It produces detailed heat maps that reflect granular, dynamic temperature changes. Unlike Landsat imagery, which offers broad, satellite-based data at a lower resolution and less frequent updates, vehicle-traverse collection can capture more specific and timely temperature variations. This method offers unique insights into localized heat patterns that can directly inform targeted design and planning interventions in landscape architecture.







MaRTy is a "mobile biometeorological instrument platform that measures air temperature, humidity, wind speed and direction, GPS coordinates, and MRT (Mean Radiant Temperature) using the 6-directional method." Photo courtesy of SHaDE Lab, Arizona State University.

#### SCALE/RESOLUTION

regional neighborhood site

#### PROJECT PHASE

pre-design design post-design

# MOBILE BIOMETEOROLOGICAL INSTRUMENT PLATFORM

## BRIEF DESCRIPTION

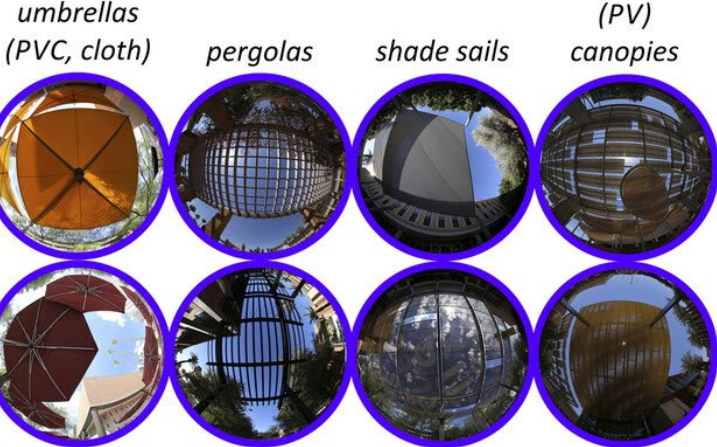
The Mobile Biometeorological Instrument Platform, known as MaRTy, is a mobile research station developed by Arizona State University (ASU). It is designed to measure and analyze various aspects of thermal comfort and heat exposure in urban environments, making it a valuable tool in the study of urban microclimates. MaRTy has the capacity to assess mean radiant temperature (MRT), which is crucial for understanding how humans experience heat in real-world conditions.

MRT is distinct from air temperature in that it accounts for all radiant heat sources a person is exposed to, including direct sunlight, reflected radiation from surrounding surfaces, and thermal radiation emitted by objects and structures in the environment. Unlike air temperature, which only measures the temperature of the air, MRT provides a more comprehensive assessment of the thermal environment as it is perceived by humans. This makes it the closest measure we have to a true

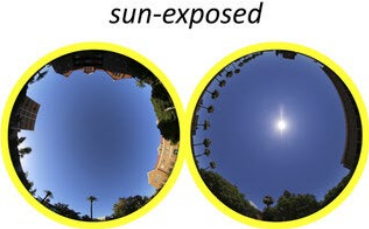
understanding of thermal comfort, as it reflects the combined effects of air temperature, solar radiation, and infrared radiation on the human body. As a result, MRT is a critical variable in evaluating the potential health risks posed by extreme heat, particularly in densely built urban areas where radiant heat can be intensified by materials like concrete and asphalt.

In the context of landscape architecture, MaRTy's ability to measure MRT allows professionals to gain deeper insights into the thermal comfort of outdoor spaces. Instead of merely identifying hotspots, MaRTy can pinpoint areas where the overall thermal experience might be uncomfortable or hazardous for people. This data enables landscape architects to design interventions that enhance thermal comfort, such as optimizing shade coverage, selecting appropriate materials, and strategically placing vegetation to reduce radiant heat exposure.

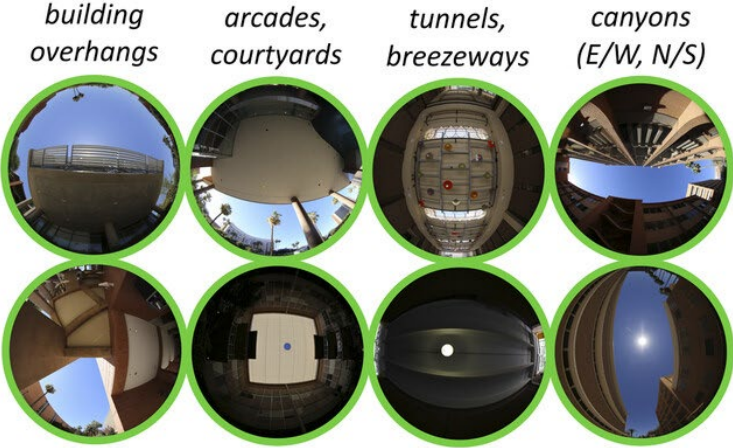
**lightweight/engineered shade**



**reference locations**



**shade from urban form**



**natural shade**





Sample of urban heat island mapping using ENVI-met, an environmental simulation software.<sup>1</sup>

#### SCALE/RESOLUTION

regional neighborhood site

#### PROJECT PHASE

pre-design design post-design

# ENVIRONMENTAL SIMULATION

## BRIEF DESCRIPTION

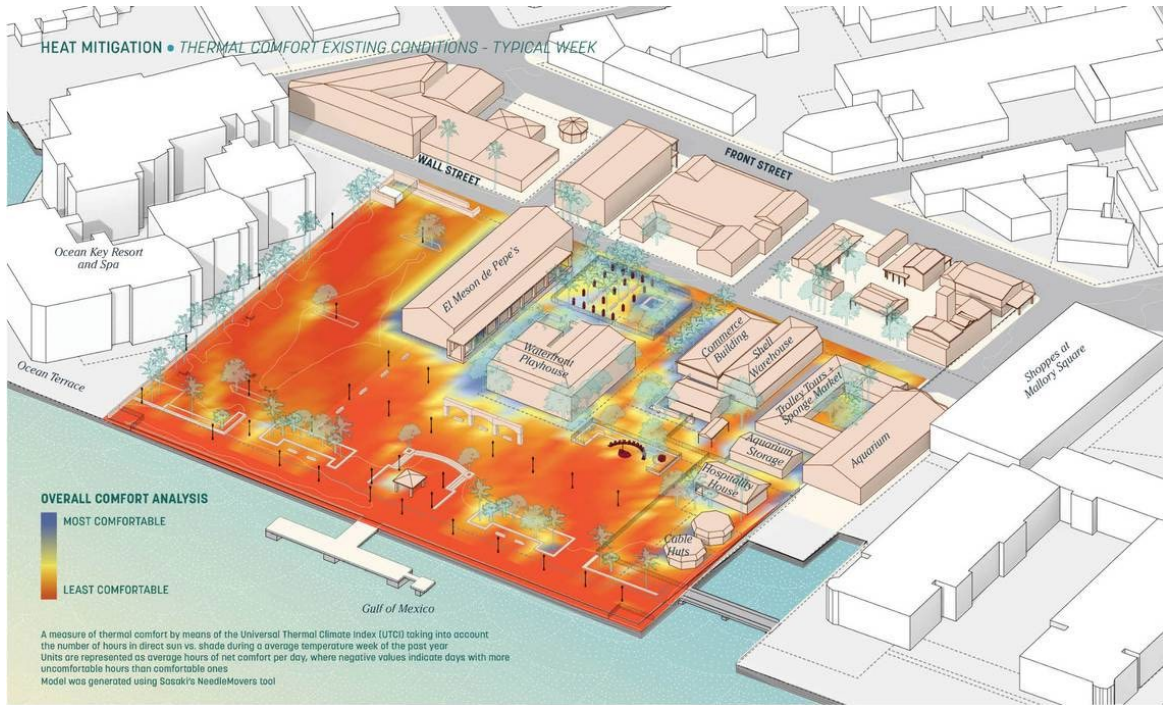
Environmental simulation is a critical process in understanding and predicting the behavior of environmental factors within built and natural environments. This practice involves using advanced computational tools to model various conditions such as temperature, humidity, wind flow, solar radiation, and their effects on buildings, landscapes, and urban spaces. By simulating these environmental conditions, designers and planners can make informed decisions that enhance sustainability, energy efficiency, and thermal comfort in their projects. Several software tools exist for environmental simulation, each offering capabilities tailored to specific aspects of environmental analysis:

ENVI-met is a popular tool, specifically designed for simulating microclimates in urban areas. It can model the interactions between buildings, vegetation, and atmospheric conditions, allowing designers to assess the impact of green spaces,

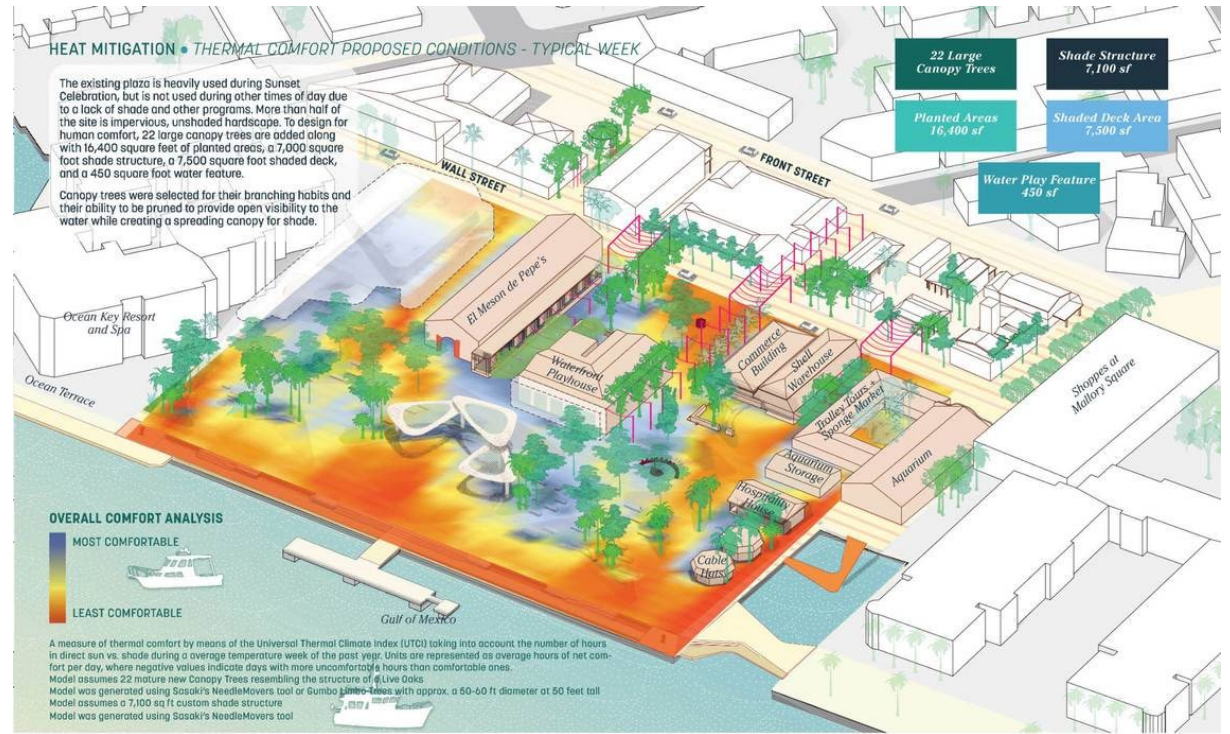
materials, and urban layouts on local temperatures and comfort levels. There are many other softwares that assist in conducting environmental assessments, but ENVI-met is one of the more commonly utilized tools, although not without its limitations, which we will describe later in this section.<sup>3</sup>

Ladybug Tools, which integrates with Rhino and Grasshopper, offers a suite of environmental analysis tools that allow for detailed simulations of sunlight, wind, and thermal comfort. These tools are particularly valuable in early design stages, enabling iterative testing of design strategies.

These software tools are instrumental in simulating thermal comfort by allowing users to predict how different design elements—such as shading, orientation, and material choices—affect the temperature and humidity experienced by occupants early in the design stage.



MALLORY SQUARE SUNSET CELEBRATION



MALLORY SQUARE SUNSET CELEBRATION



*"Engaging Heat" community engagement exercise with residents of the South Omaha neighborhood. Photo by Salvador Lindquist.*

#### SCALE/RESOLUTION

regional neighborhood site

#### PROJECT PHASE

pre-design design post-design

# COMMUNITY-LED HEAT ASSESSMENT

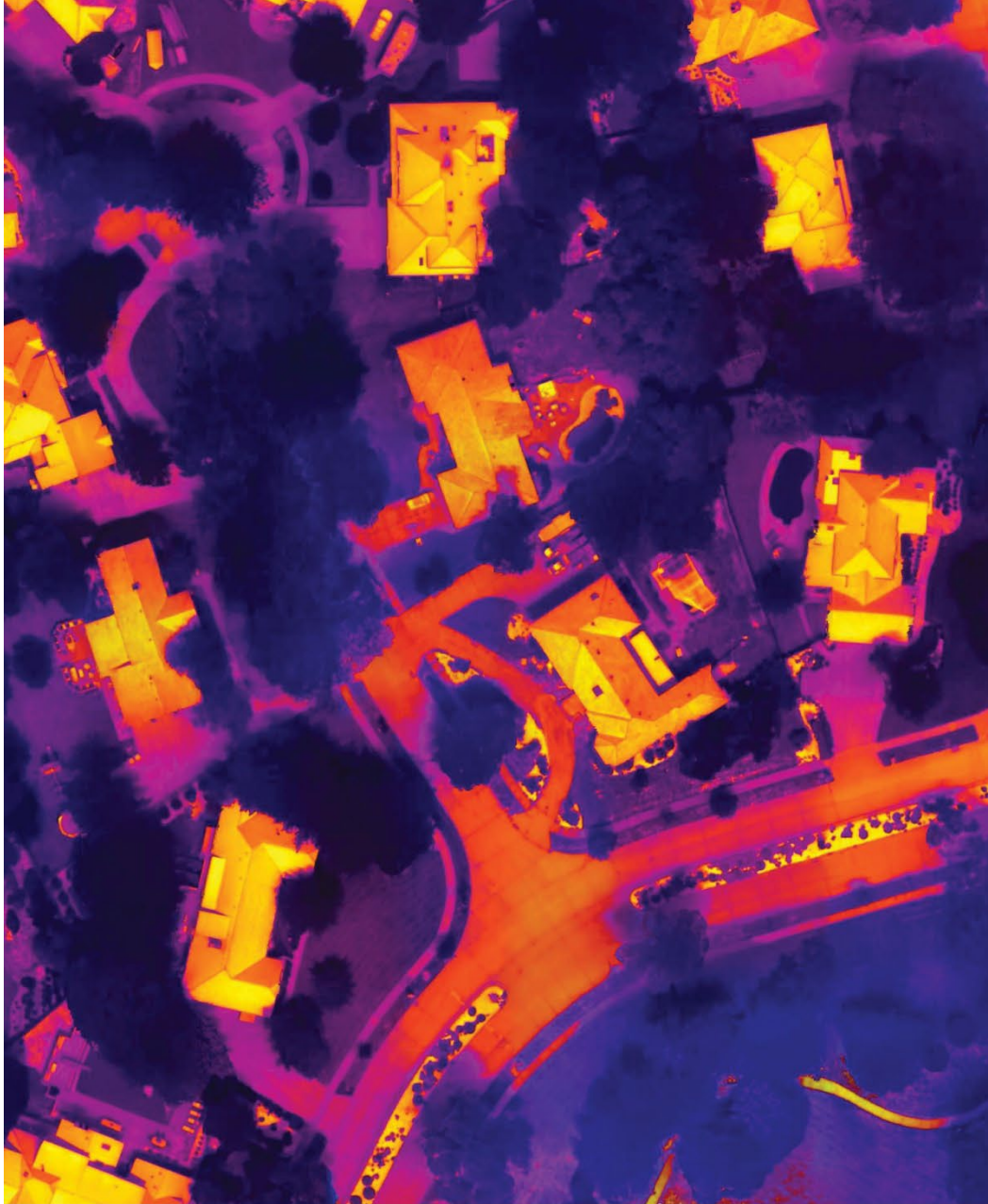
## BRIEF DESCRIPTION

Community-led heat assessments are a participatory approach to evaluating the impacts of extreme heat within urban environments. Unlike traditional heat measurement tools, such as Landsat imagery, UAV thermography, and handheld thermal sensors, these assessments involve local residents in the data collection and analysis process. This grassroots methodology offers unique insights into heat exposure that may be missed by more conventional methods.

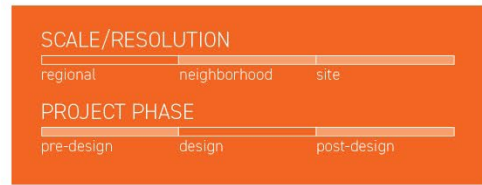
Community-led assessments typically involve training residents to use simple tools, like temperature loggers or mobile apps, to record heat conditions in their neighborhoods. Participants might also conduct surveys to gather qualitative data on their experiences with heat, including health impacts and access to cooling resources. This approach allows for the collection of data from a variety of micro-environments that might not be captured by broader, less granular methods.

One of the primary advantages of community-led assessments is their ability to capture localized heat experiences that are often overlooked by traditional tools. While Landsat imagery provides broad, satellite-based data, and UAV and handheld thermography offer high-resolution temperature readings, these methods often miss nuanced variations at the street level. Community-led assessments can identify specific hotspots and vulnerable areas based on direct, lived experiences of residents, revealing how different demographics are affected by extreme heat.

Furthermore, community involvement fosters greater engagement and empowerment, ensuring that the solutions and recommendations are directly informed by those most impacted. This participatory approach can lead to more effective and equitable heat adaptation strategies, as it considers the unique needs and challenges of various communities.



Streetscape thermal enlargement of the Regency corridor scan. Thermal scan by Keenan Gibbons.



# UAV THERMOGRAPHY

## BRIEF DESCRIPTION

UAV Thermography refers to the use of Unmanned Aerial Vehicles (UAVs), commonly known as drones, equipped with thermal imaging cameras to capture and analyze heat patterns from an aerial perspective. These specialized cameras detect infrared radiation emitted by objects and surfaces, converting this data into visual images that represent temperature variations. By analyzing the thermal data, UAV thermography can reveal how heat is distributed across different areas, highlighting hot and cool zones with high precision.

The process of UAV thermography involves flying the drone over a specified area, where it captures thermal images that are processed into detailed maps. These maps use color gradients to indicate temperature differences, with warmer areas typically represented by reds and oranges, and cooler areas by blues and greens. This visual representation of heat distribution helps in identifying hotspots or areas of interest that may

require further investigation or intervention. In the field of landscape architecture, UAV thermography is a powerful tool for understanding microclimates within urban environments. Professionals can use this technology to identify areas where heat is disproportionately concentrated, such as on concrete surfaces, rooftops, or sparsely vegetated zones. This information is crucial when designing or retrofitting urban spaces to improve thermal comfort and reduce the urban heat island effect.

For instance, landscape architects can use UAV thermography to assess the effectiveness of green infrastructure, such as green roofs, tree canopies, and parks, in cooling urban environments. By comparing thermal maps taken before and after the implementation of such features, they can quantitatively evaluate their impact on reducing surface temperatures. Additionally, this tool can be used to monitor the performance of existing landscapes over time, ensuring that they continue to provide the intended cooling benefits.



Handheld thermal image of an ADA ramp at the Gene Leahy Mall.

#### SCALE/RESOLUTION

regional neighborhood site

#### PROJECT PHASE

pre-design design post-design

# HANDHELD THERMOGRAPHY

## BRIEF DESCRIPTION

Handheld Thermography involves using portable thermal imaging cameras to capture infrared radiation emitted by surfaces, converting this data into visual heat maps. Unlike UAV thermography, which provides broader aerial views, handheld thermography allows for a more detailed and granular examination of specific surfaces and materials at close range. This close-up capability enables landscape architects to assess thermal variations on surfaces like pavements, building facades, or vegetation, which are often missed in broader UAV scans.

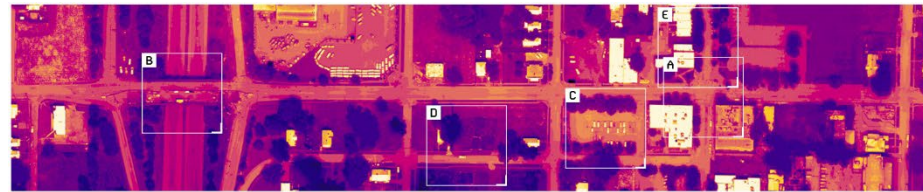
One of the key advantages of handheld thermography is its ability to pinpoint specific thermal anomalies or variations in real time. While UAVs provide an expansive overview, handheld devices allow practitioners to dive deeper into particular areas of interest, such as identifying heat retention in different materials or the cooling effects of specific vegetation. This level of detail is crucial

for understanding the nuances of thermal comfort in outdoor spaces and the performance of different landscape elements under heat stress.

In landscape architecture practice, handheld thermography enhances the way heat is visualized by allowing for an on-the-ground perspective. It enables designers to gather data from hard-to-reach areas or locations that require more detailed analysis, such as shaded versus unshaded areas or the thermal performance of specific plant species. This tool helps in creating more precise heat maps, which can inform the placement of shade structures, vegetation, and other cooling strategies.

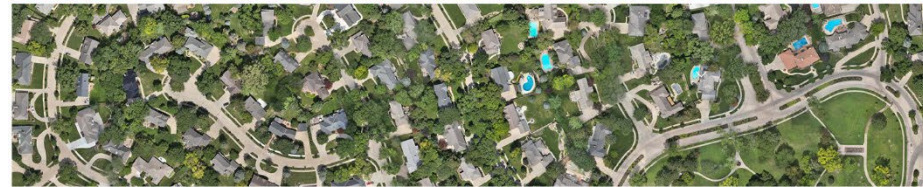
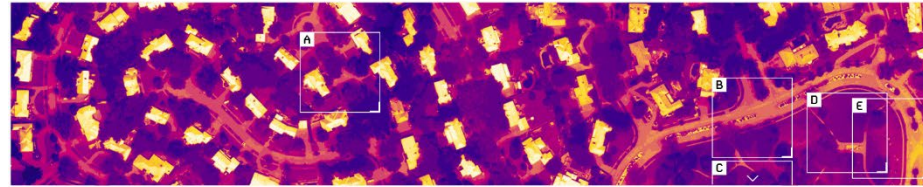
Furthermore, handheld thermography's portability makes it an ideal tool for iterative design processes, where designers can test and visualize the thermal impacts of various interventions on-site, making adjustments in real-time. This approach fosters a more responsive and adaptive design process, leading to more effective and targeted heat mitigation strategies in urban landscapes.





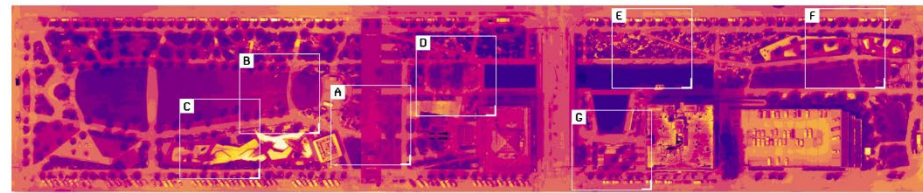
**A** STREET INTERSECTION      **D** COMMUNITY GARDEN  
**B** INTERSTATE OVERPASS      **E** STREETSCAPE  
**C** PARKING LOT

**75 NORTH**



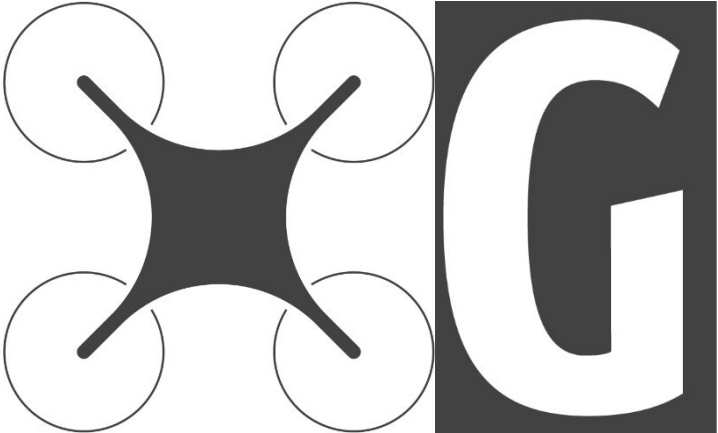
**A** STREETSCAPE      **D** PARK/GREEN SPACE  
**B** BOULEVARD      **E** NEIGHBORHOOD GATEWAY  
**C** PLAYGROUND

**REGENCY**



**A** PLAZA      **E** STREETSCAPE  
**B** CENTRAL LAWN      **F** DOG PARK  
**C** PLAYGROUND      **G** AMPHITHEATER  
**D** SPLASH PAD

**GENE LEAHY MALL**



# SG UAV

2018



**AJ Noto**



**Tommy Reyna**



**Matthew Medley**



**Keenan Gibbons**

# SG UAV

2018



*DJI Phantom 4 RTK*



*DJI Matrice 210 RTK*

# SG UAV

2024



Lindsey Mathus



Lichao Liu



Laura Holman



AJ Noto



Keenan Gibbons



Luis Bribiesca



Rob Kish



Bill Roznik



Tim  
VanOudenhoven



Katherine DeKrey



Dustin Simmons



Juan Arias



Mrunmayee Atre



Ryan Dashkevicz



Ginny Rice



Julius Taniguchi



# SG UAV



*DJI Mavic 3E*



*DJI Mavic 3T*



*DJI Mavic 3T*



*DJI Mavic 3T*



*DJI Mavic 3T*



*DJI Mavic 3T*



*DJI Mavic 3T*



*DJI Mavic 3T*

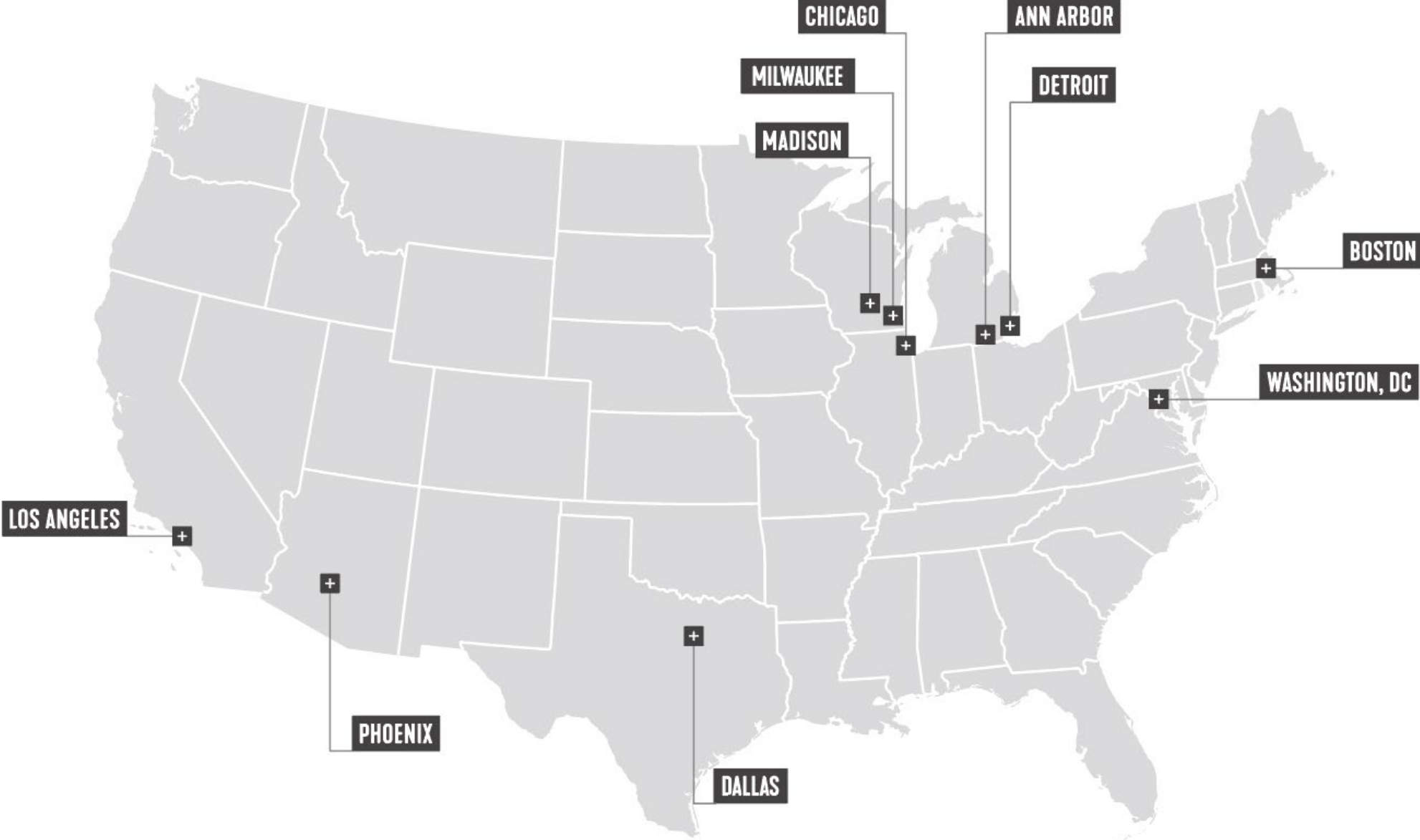


*DJI Phantom 4 RTK*



*DJI Matrice 210 RTK*

# SG UAV

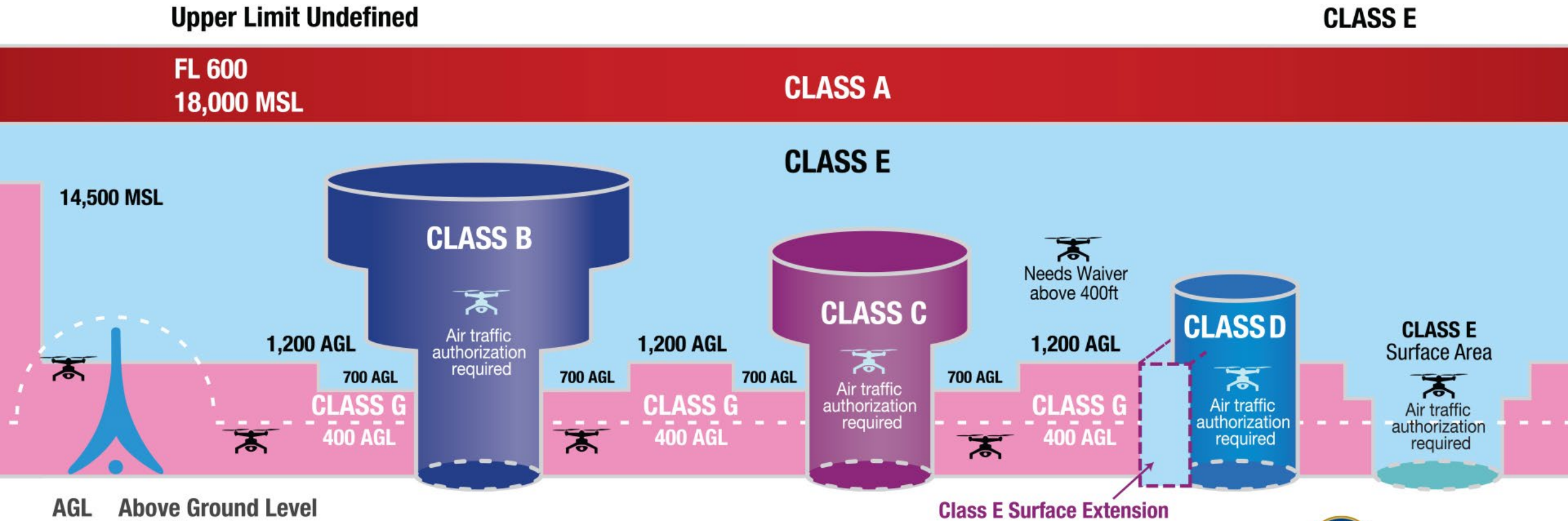


# UAV NOMENCLATURE

- **UAV:** (drones) are also referred to as UAS or sUAS. They basically mean the same thing.
- **3D photogrammetry:** overlapping 2D imagery to process surface models and orthos.
- **Orthomosaic / orthoimagery:** the 'stitching together' of georeferenced 2D images.
- **RTK (Real Time Kinematic):** GPS capability to produce replicate saved flightpaths within 1cm on X,Y,Z.
- **FAA Remote Pilot, Part 107 Regulations:** this "drone license" is required to conduct flights as a professional service for compensation.
- **Controlled Airspace:** What is it? Why does it matter?



# FAA AIRSPACE



## Airspace Guidance for Small UAS Operators

Source: FAA



Federal Aviation Administration



*DJI Matrice 210 RTK*



*Zenmuse XT2 Thermal Camera*

# NOVEL RESEARCH + PILOT PROJECT

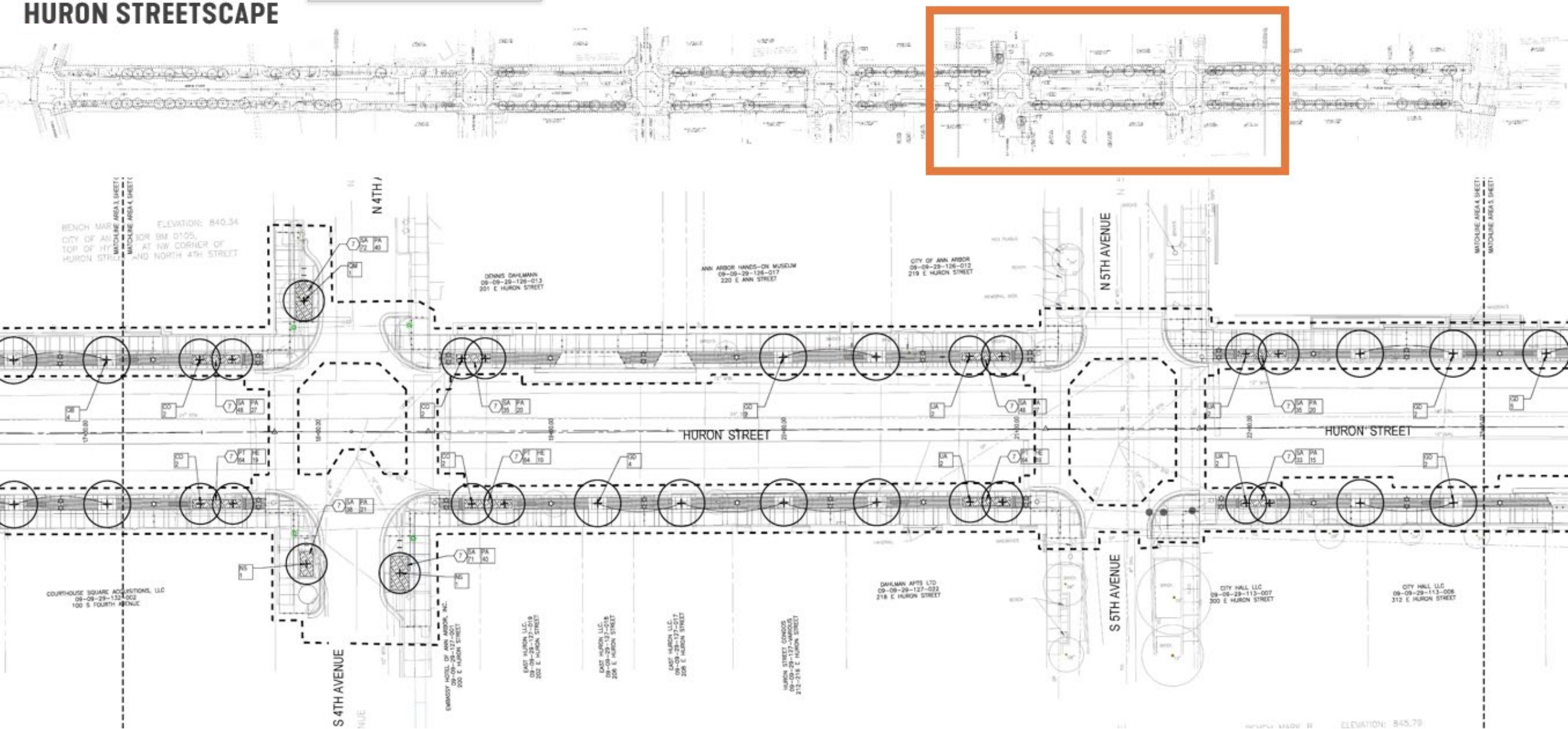
**PROJECT:** HURON STREETScape  
**LOCATION:** ANN ARBOR, MICHIGAN  
**COST:** \$4.5M = OVERALL  
\$400K = TREES + PLANTING  
[130 SHADE TREES]  
**CONSTRUCTION:** SUMMER 2019 – WINTER 2019

**1<sup>ST</sup> FLIGHT / SCAN:** JUNE/JULY 2019  
**2<sup>ND</sup> FLIGHT / SCAN:** JUNE/JULY 2020  
**3<sup>RD</sup> FLIGHT / SCAN:** JUNE/JULY 2024?

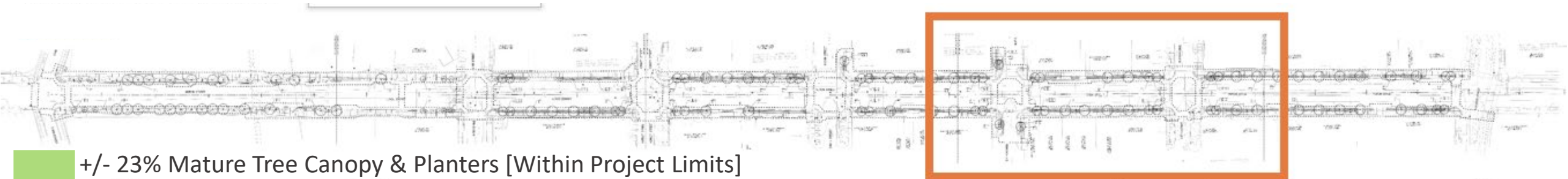


# NOVEL RESEARCH + PILOT PROJECT

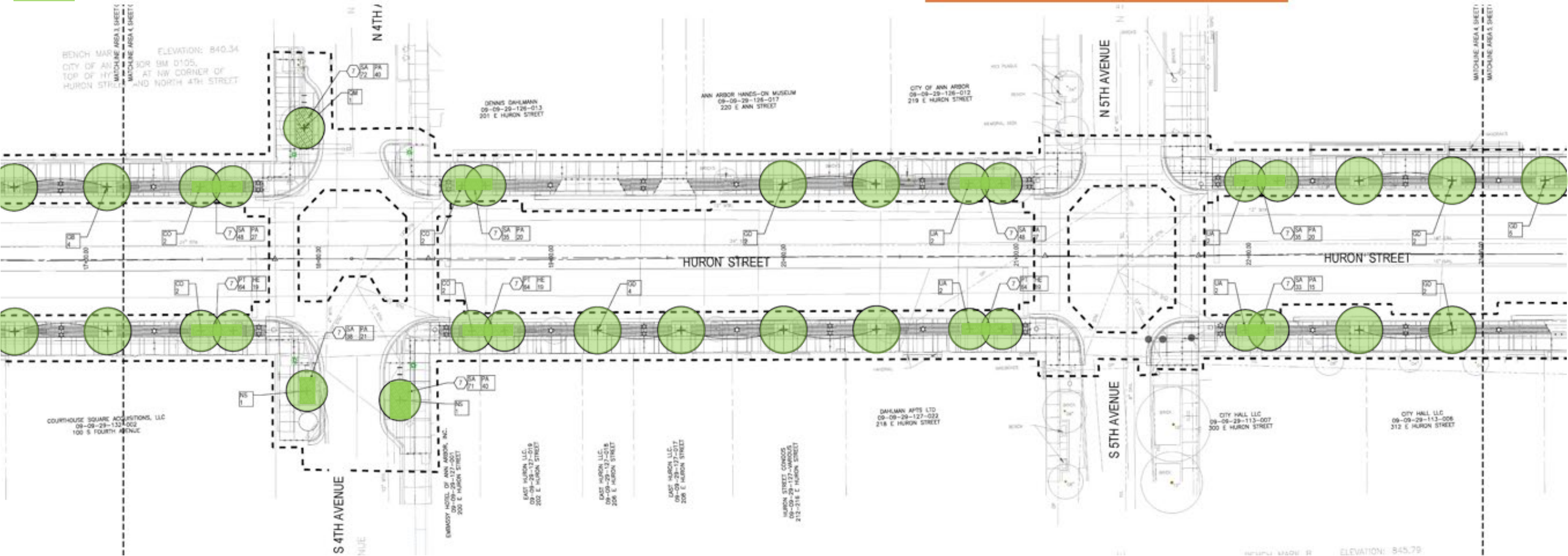
## HURON STREETScape



# NOVEL RESEARCH + PILOT PROJECT



+/- 23% Mature Tree Canopy & Planters [Within Project Limits]



# NOVEL RESEARCH + PILOT PROJECT



# NOVEL RESEARCH + PILOT PROJECT

→ **METAR text:** **KARB 211653Z 29009KT 10SM SCT039 29/20 A2993 RMK AO2 SLP129 T02890200**

**Conditions at:** KARB (ANN ARBOR , MI, US) observed 1653 UTC 21 August 2019

**Temperature:** 28.9°C (84°F)

**Dewpoint:** 20.0°C (68°F) [RH = 59%]

**Pressure (altimeter):** 29.93 inches Hg (1013.6 mb)  
[Sea-level pressure: 1012.9 mb]

**Winds:** from the WNW (290 degrees) at 10 MPH (9 knots; 4.6 m/s)

**Visibility:** 10 or more miles (16+ km)

**Ceiling:** at least 12,000 feet AGL

**Clouds:** scattered clouds at 3900 feet AGL

**Weather:** no significant weather observed at this time







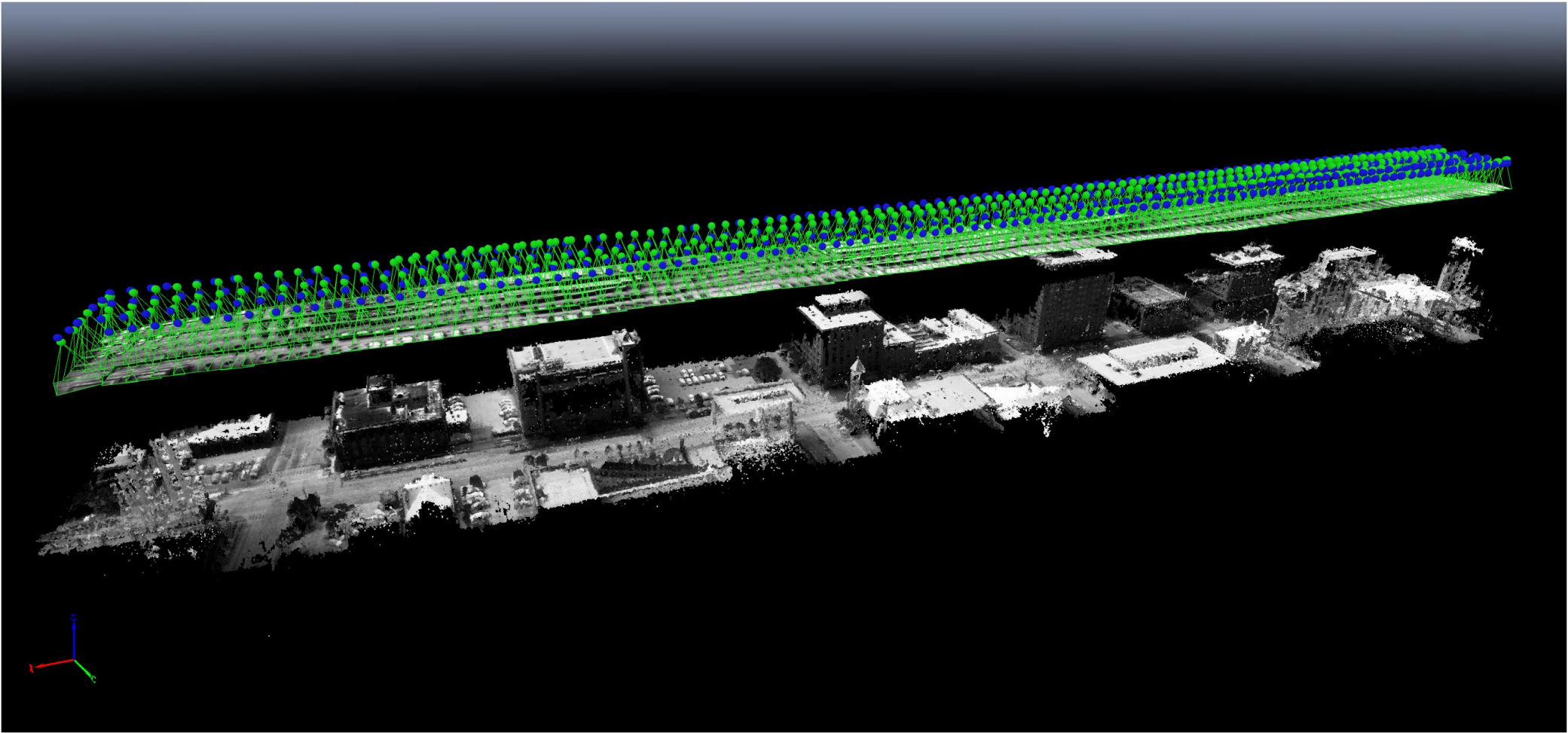
# NOVEL RESEARCH + PILOT PROJECT

The screenshot displays a drone flight application interface. At the top, it shows 'In-Flight (GPS)' and 'F-WP' (Flight Waypoint) controls. A flight path is plotted in green over an aerial view of a city street grid, with waypoints labeled 'A', 'B', and 'C'. A red 'X' icon and a white pause icon are visible on the left side of the map. The bottom of the screen features a data panel with the following information:

Height	200ft	V.S.	0mph	Photos	
Distance	997ft	H.S.	2mph		406 / 419
Lat	+42.281284	Lng	-83.748524		

Additional data shown includes 'Estimated 2m16s left', '94%' battery, and 'FPV' (First Person View) camera feed. The flight path is approximately 1,650 feet long, as indicated by a white dimension line.

# POST-PROCESSING UAV THERMAL IMAGING & PHOTOGRAMMETRY



# POST-PROCESSING UAV THERMAL IMAGING & PHOTOGRAMMETRY

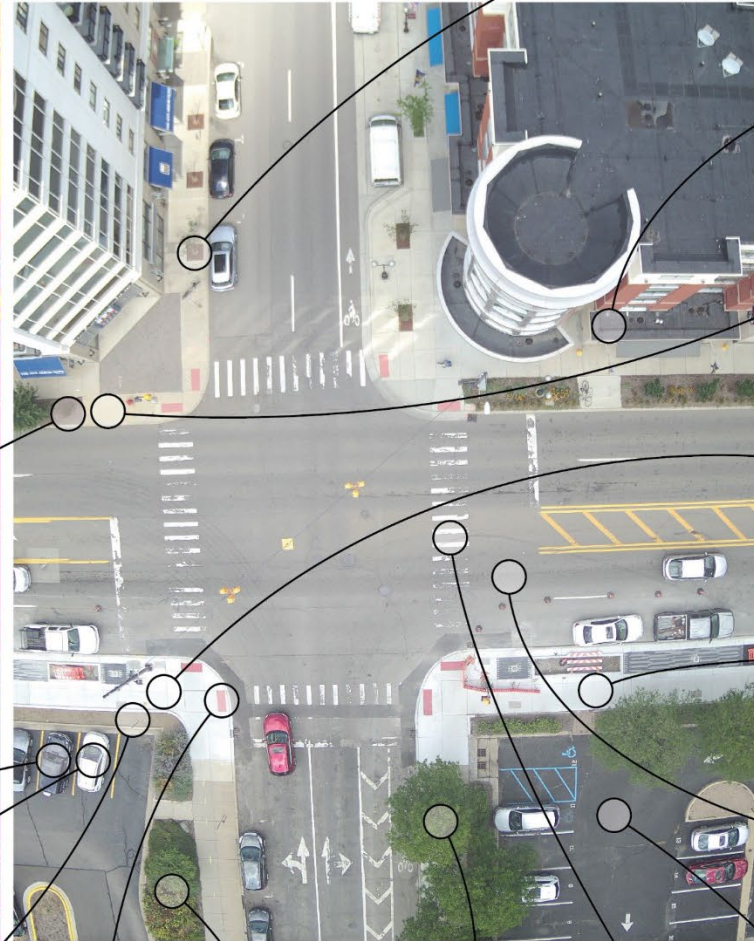
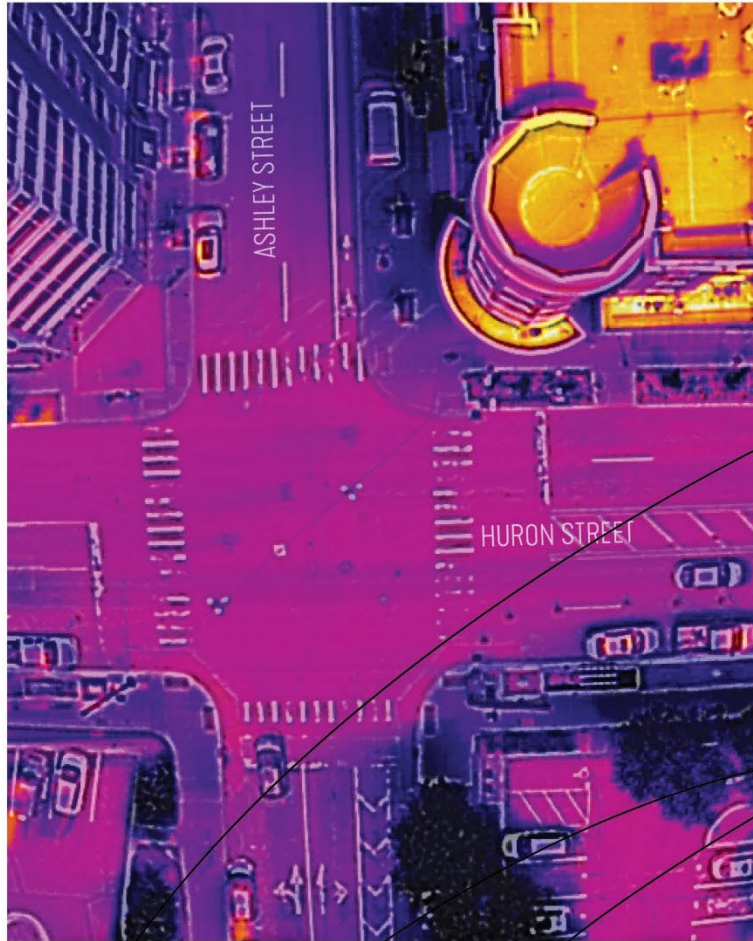


# THE URBAN HEAT ISLAND EFFECT MATERIAL PALETTE

Wednesday, August 21, 2019 • Ann Arbor, Michigan



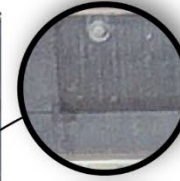
AIR TEMP  
84°F



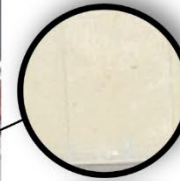
SMITHGROUP



IRON TREE GRATE  
116°F



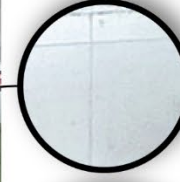
BITUMEN ROOFTOP  
153°F



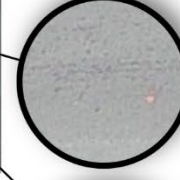
WEATHERED CONCRETE  
110°F



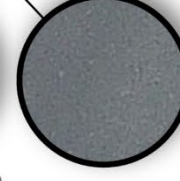
NEW CONCRETE  
100°F



SHADED CONCRETE  
89°F



WEATHERED ASPHALT  
112°F



NEW ASPHALT  
116°F



MULCH  
124°F



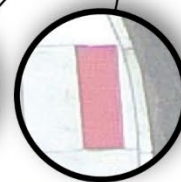
BLACK CAR  
126°F



WHITE CAR  
102°F



SOIL  
106°F



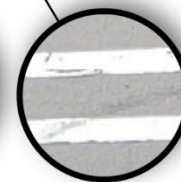
WARNING STRIP  
109°F



SHRUBS  
87°F



TREE  
86°F



WHITE STRIPING  
106°F

# SOLAR NOON IN THE URBAN HEAT ISLAND

Huron Streetscape Project, Existing Conditions • Ann Arbor, Michigan • Wednesday, August 21, 2019



1:24PM FLIGHT

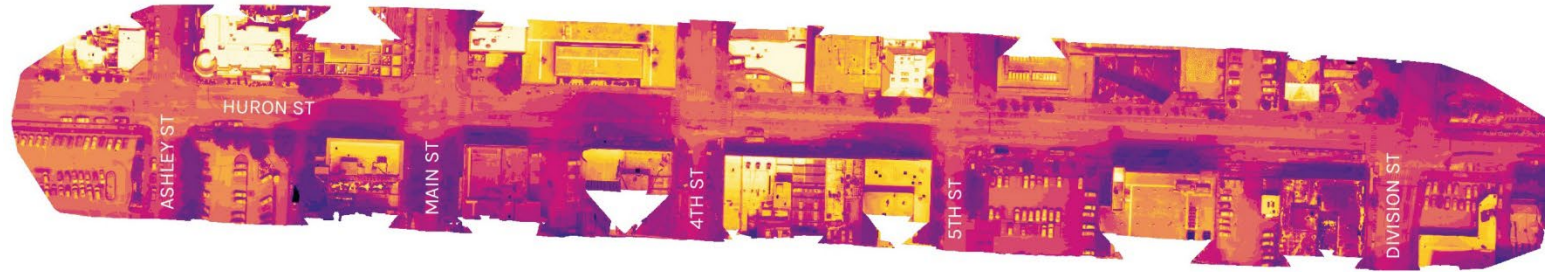
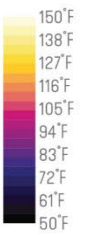
84°F AIR TEMP

SURFACE TYPE:

BUILDING	4.04 AC [35% AREA]
SIDEWALK	2.14 AC [19% AREA]
ASPHALT	4.69 AC [40% AREA]
VEGETATION	.64 AC [6% AREA]

AREA:

11.51 AC [100% AREA]



## BREAKDOWN



**COOL SPOTS**

80°F - 104°F [Δ 24°F]

SURFACE TYPE:

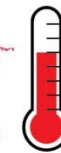
AREA:

**42% SURFACE AREA**

UP TO 20°F > AIR TEMP

VEGETATION, SHADED CONCRETE  
SIDEWALK & ASPHALT

4.48 AC [42.4% AREA]



**WARM SPOTS**

104°F - 118°F [Δ 14°F]

SURFACE TYPE:

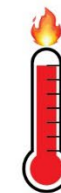
AREA:

**42% SURFACE AREA**

UP TO 34°F > AIR TEMP

PASSIVELY EXPOSED CONCRETE &  
ASPHALT

4.84 AC [41.9% AREA]



**HOT SPOTS**

118°F - +150°F [Δ 32°F]

SURFACE TYPE:

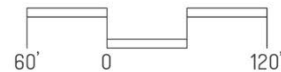
AREA:

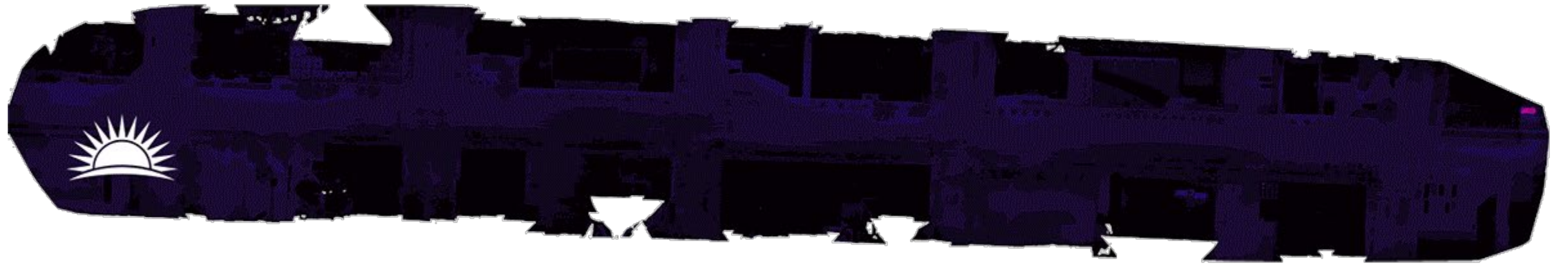
**16% SURFACE AREA**

UP TO +66°F > AIR TEMP

CONTINUOUSLY EXPOSED HIGH  
EMISSIVITY ROOFTOPS

1.80 AC [15.6% AREA]





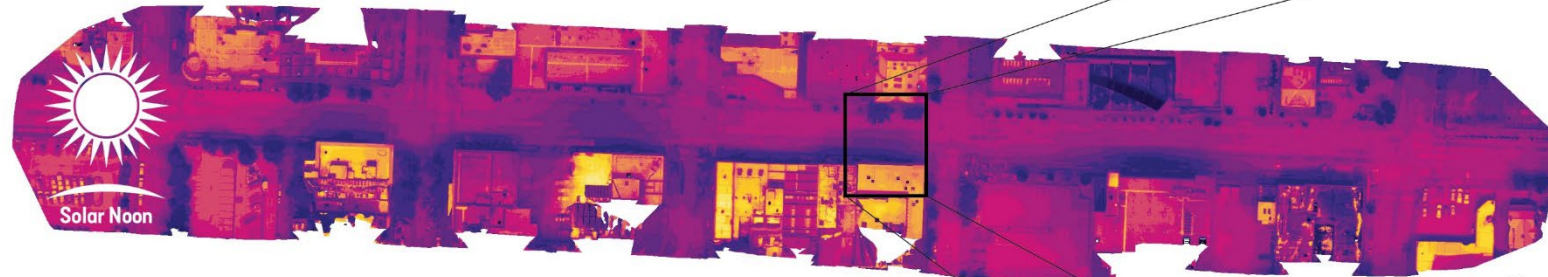
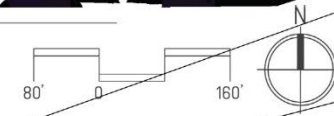
# A DAY IN THE URBAN HEAT ISLAND

Huron Streetscape Project, Existing Conditions • Ann Arbor, Michigan • Sunday, August 25, 2019



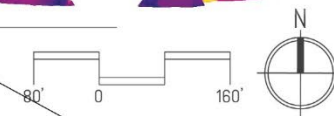
## 6:34AM FLIGHT

AIR TEMP: 61°F [16.1°C]  
 MAX TEMP: 76°F [24.2°C]  
 MIN TEMP: 36°F [2.2°C]  
 Δ MAX-MIN TEMP: 40°F [16.1°C]  
 Δ MAX-AIR TEMP: 15°F [8.1°C]



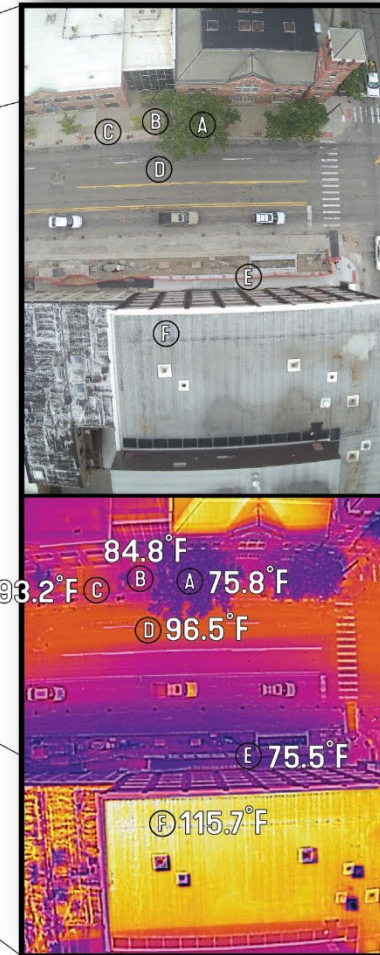
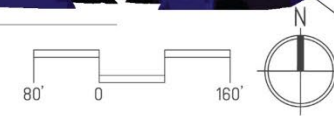
## 1:23PM FLIGHT

AIR TEMP: 74°F [23.3°C]  
 MAX TEMP: 127°F [52.5°C]  
 MIN TEMP: 62°F [16.5°C]  
 Δ MAX-MIN TEMP: 65°F [36.0°C]  
 Δ MAX-AIR TEMP: 53°F [29.2°C]



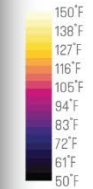
## 8:11PM FLIGHT

AIR TEMP: 70°F [21.1°C]  
 MAX TEMP: 96°F [35.8°C]  
 MIN TEMP: 42°F [5.8°C]  
 Δ MAX-MIN TEMP: 54°F [30.0°C]  
 Δ MAX-AIR TEMP: 26°F [14.7°C]



## MATERIAL

- (A) TREE
- (B) TREE SHADE
- (C) SIDEWALK
- (D) ASPHALT
- (E) BUILDING SHADE
- (F) BUILDING ROOF





# NOT ALL GREEN SPACE IS EQUAL

MOWED LAWN  
108.6°F

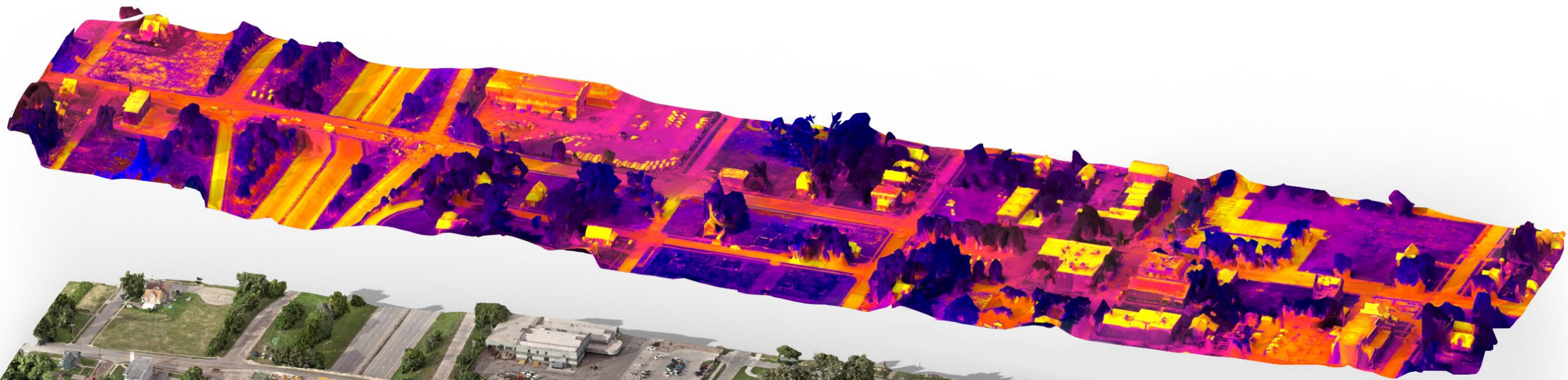


NATIVE PRAIRIE  
85.1°F

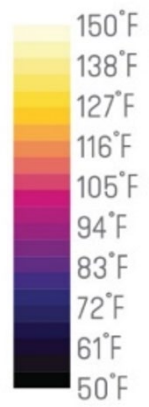


 keenan.gibbons

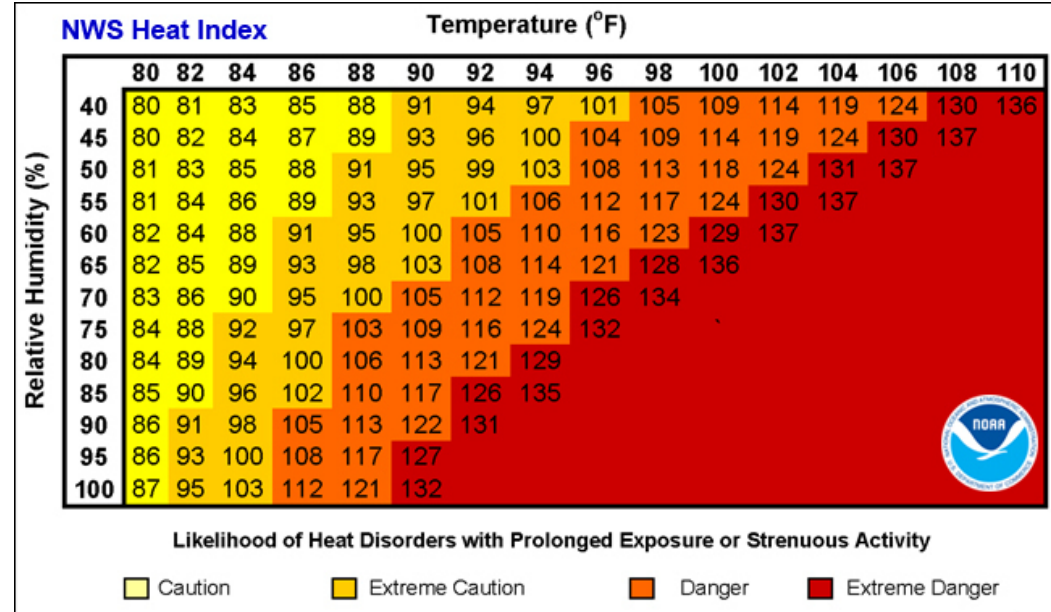
AUGUST 18, 2021 • OKEMOS, MI • 82°F





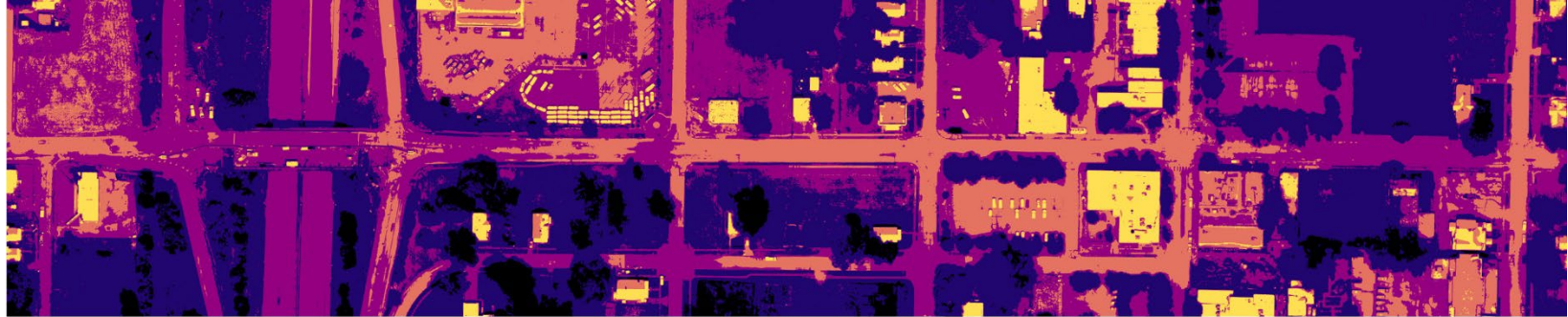
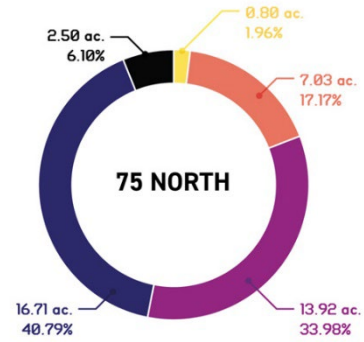


- Extreme Danger [125°F or higher]
- Danger [103°F - 124°F]
- Extreme Caution [90°F - 102°F]
- Caution [80°F - 90°F]
- Mild Caution [79°F or lower]

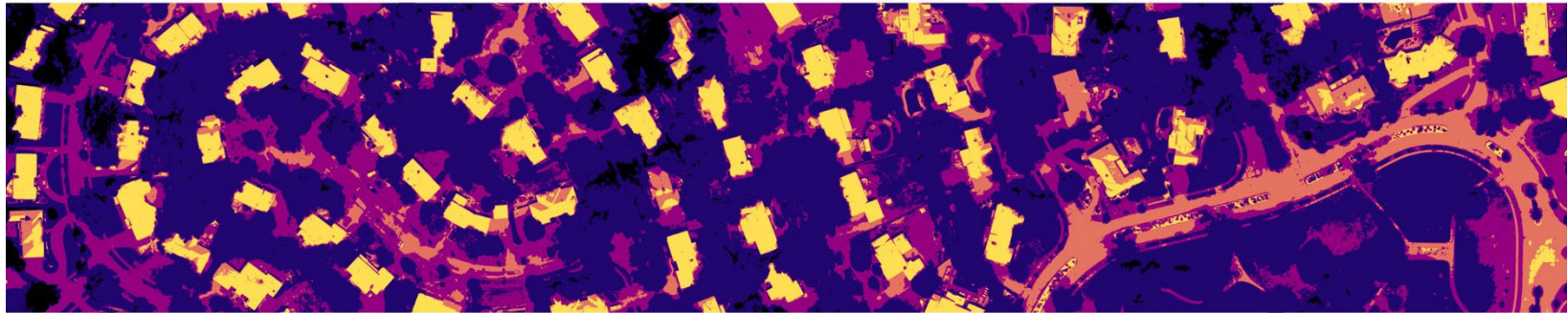
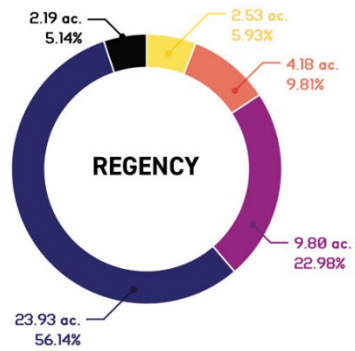


Classification	Heat Index	Effect on the body
Caution	80°F - 90°F	Fatigue possible with prolonged exposure and/or physical activity
Extreme Caution	90°F - 103°F	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity
Danger	103°F - 124°F	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity
Extreme Danger	125°F or higher	Heat stroke highly likely

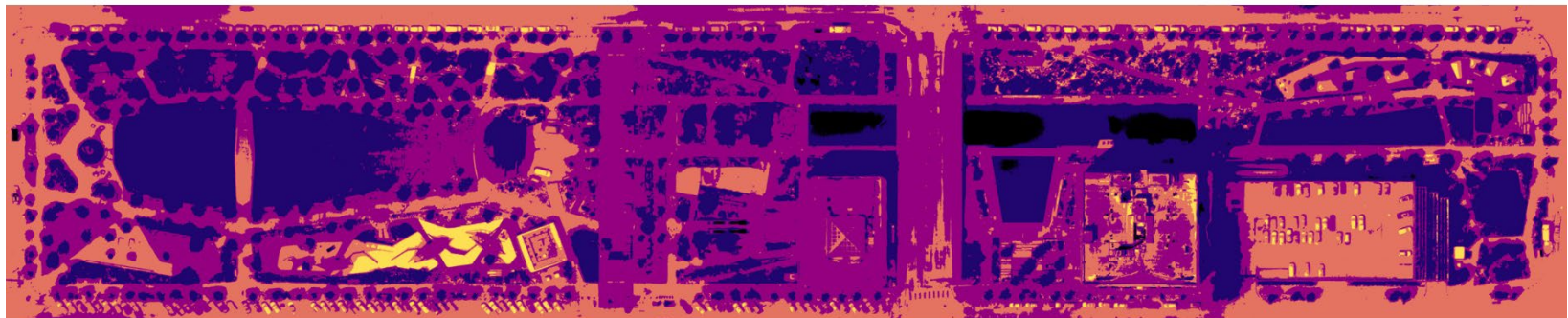
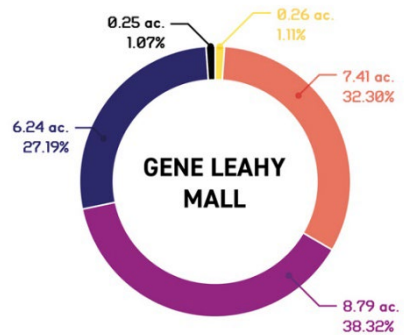
- Extreme Danger [125°F or higher]
- Danger [103°F - 124°F]
- Extreme Caution [90°F - 102°F]
- Caution [80°F - 90°F]
- Mild Caution [79°F or lower]



75 NORTH

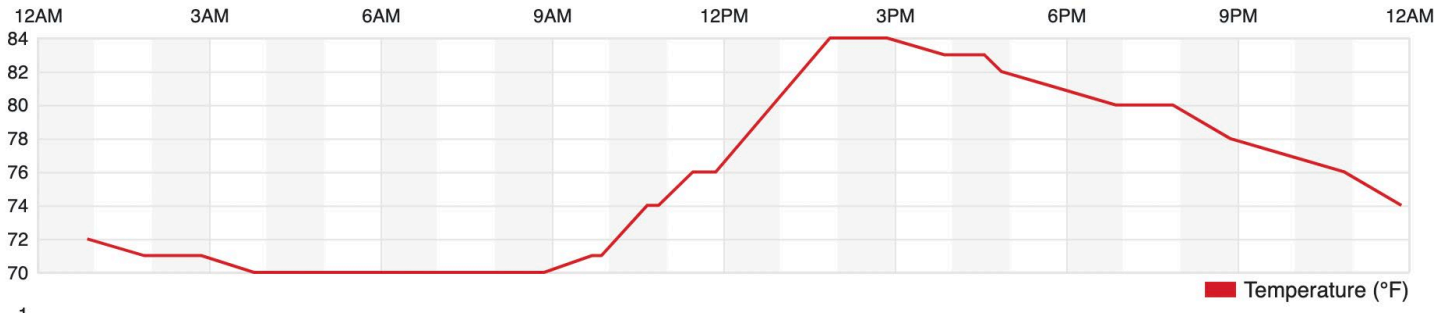


REGENCY



GENE LEAHY MALL

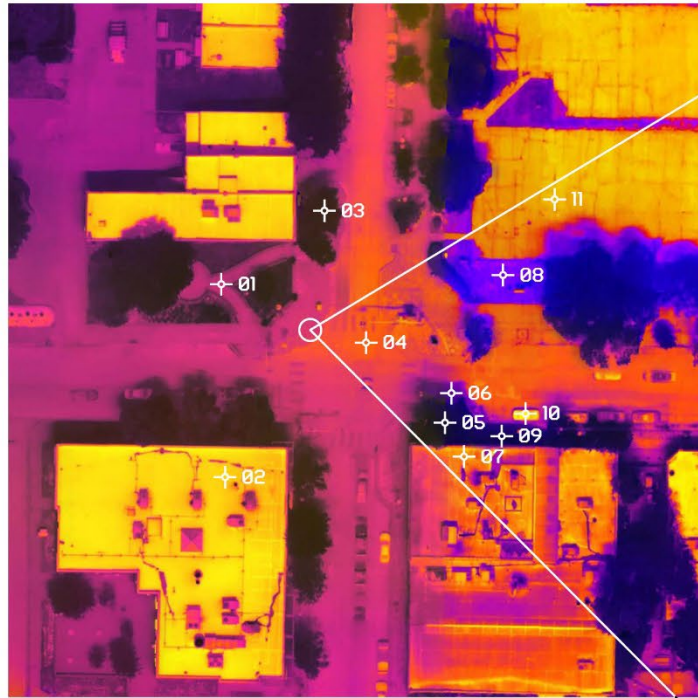
SPOT	MATERIAL	TEMP.
01	Concrete (Sidewalk; Sun)	108.0° F
02	Bituminous Roof (Black; Sun)	150.4° F
03	Tree Canopy	82.9° F
04	Concrete (Road; Sun)	113.0° F
05	Tree Canopy	82.2° F
06	Concrete (Road; Shade)	90.5° F
07	Bituminous Roof (White; Sun)	119.3° F
08	Lawn (Sun)	97.5° F
09	Concrete (Sidewalk; Shade)	85.6° F
10	Automobile (Black; Sun)	138.4° F
11	Asphalt (Sun)	107.2° F



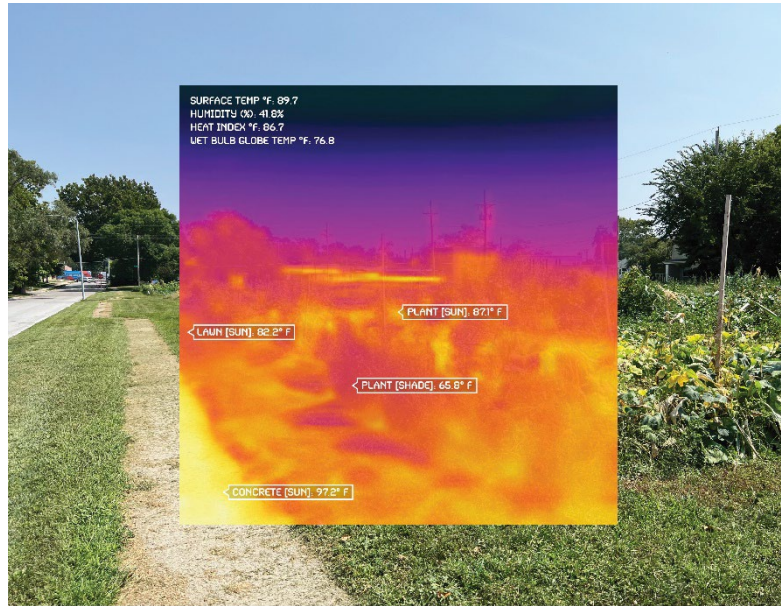




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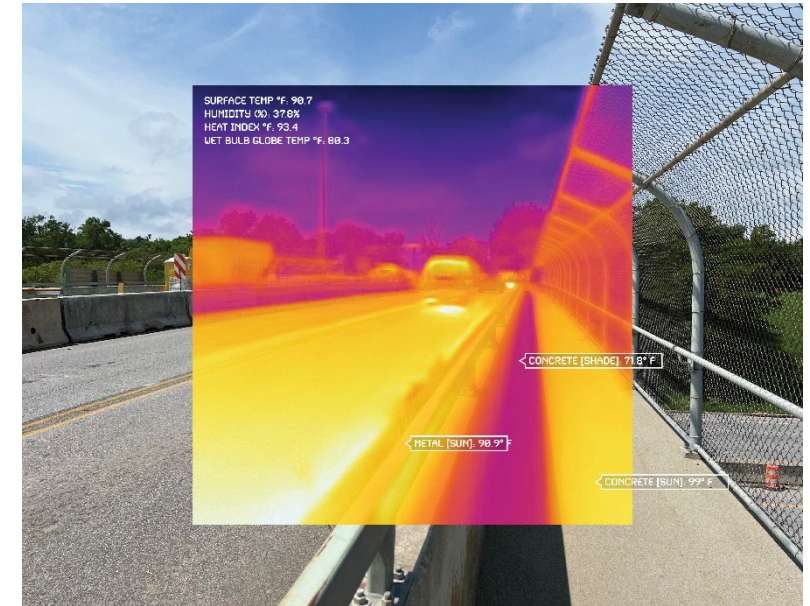
# 75 NORTH



COMMUNITY GARDEN



STREET INTERSECTION



INTERSTATE OVERPASS

# REGENCY



PLAYGROUND

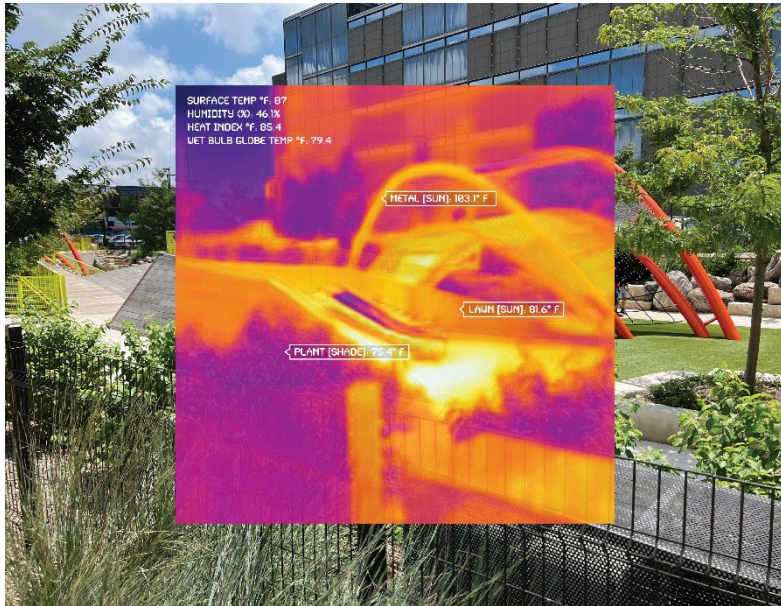


BOULEVARD



STREET INTERSECTION

# GENE LEAHY MALL



PLAYGROUND



PLAZA/HARDSCAPE



STREETSCAPE

# 04

## DISCUSSION AND CONCLUSION

- A UAV Thermography
- B Ground Thermography

# 75 NORTH CORRIDOR

material surface temperature **1000 K°F**

**INTERSTATE OVERPASS**  
Interstate overpasses often exhibit elevated thermal conditions due to materials like concrete absorbing and radiating heat. The lack of vegetation and proximity to vehicular traffic contribute to increased temperatures, creating localized heat pockets within urban environments.

**CONCRETE PARKING LOT**  
Concrete parking lots intensify thermal conditions, absorbing and radiating heat. The lack of vegetation exacerbates heat retention. The high albedo of concrete can have localized cooling benefits, creating heat islands within urban areas and affecting overall thermal comfort.

**BLACK BITUMINOUS ROOF**  
Black bituminous roofs absorb and retain heat, elevating temperatures in urban areas. The low albedo of these roofs contributes to some of the hottest material surface temperatures in the city. The absorbed heat can affect overall energy consumption and impact the surrounding environment.

**POCKET PARK**  
Pocket parks enhance thermal conditions by introducing greenery into urban spaces. The vegetal cover provides shade, reducing surface temperatures. These small green patches contribute positively to local microclimates and enhance overall thermal comfort within urban environments.

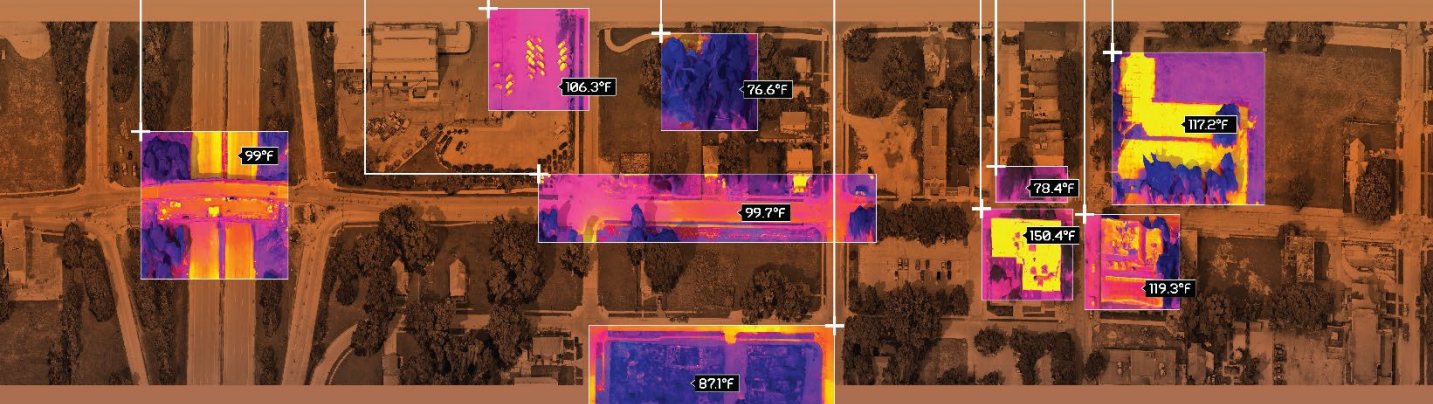
**WHITE BITUMINOUS ROOF**  
White bituminous roofs, with higher albedo, reflect more sunlight, lowering material surface temperatures. This contrasts with black bituminous roofs, which absorb heat. White roofs contribute to cooler urban environments and decreased energy consumption.

**DISCONTINUOUS STREET TREES**  
Discontinuous street trees provide limited shade, insufficiently cooling urban areas. Gaps between trees reduce their overall effectiveness in mitigating heat. The compromised green canopy results in uneven thermal conditions, impacting local temperatures and thermal comfort within the urban environment.

**URBAN ECO-PATCH**  
Urban eco-patches, featuring vegetation resulting from a lack of maintenance, offer partial contributions to thermal conditions. These spontaneous green spaces contribute to local cooling, biodiversity, and overall urban resilience.

**COMMUNITY GARDEN**  
Community gardens contribute positively to thermal conditions by introducing vegetation into the urban landscape. The presence of green spaces enhances local microclimates, mitigating the urban heat island effect, and promoting overall thermal comfort within the community.

**ASPHALT PARKING LOT**  
Dark asphalt parking lots, with lower albedo, absorb and retain more heat, elevating material surface temperatures. In contrast with concrete parking lots, asphalt is much hotter, creating localized heat pockets and contributing to higher temperatures in urban areas.



## THERMAL CONDITIONS

North Omaha is a historically significant area with a unique demographic and urban condition. The neighborhood has a complex history, shaped by redlining policies that were prevalent in the mid-20th century. Redlining, a discriminatory practice by which certain neighborhoods were marked as high-risk for lending or insurance based on racial composition, has had lasting effects on North Omaha. One of the prominent demographic features of North Omaha is its higher percentage of Black population. This is a result of historical segregation and discrimination, as Black residents were often confined

to specific neighborhoods due to restrictive housing policies. The challenges associated with the urban condition in North Omaha, particularly those stemming from historical redlining and economic disparities, contribute significantly to thermal disparities within the community, particularly in the context of the urban heat island (UHI) effect. One key factor is the unequal distribution of green spaces and tree cover in North Omaha. The redlining policies have led to disinvestment and limited resources in the area, resulting in fewer parks and green spaces in neighborhoods with limited green infrastructure,

as North Omaha, there is a higher likelihood of increased temperatures, creating thermal disparities within the urban landscape. Moreover, the quality of housing and infrastructure in North Omaha also plays a role in contributing to thermal disparities. The economic challenges faced by the community may lead to substandard housing conditions, with inadequate insulation and ventilation. Such housing situations can result in higher indoor temperatures, further intensifying the overall thermal conditions experienced by residents. The urban heat island effect is often exacerbated by the prevalence of im-

pervious surfaces like asphalt and concrete in urban areas. In North Omaha, historical disinvestment may have led to limited infrastructure improvements, contributing to a higher proportion of impervious surfaces. These surfaces absorb and retain heat, intensifying the UHI effect and creating localized hotspots within the community. ■

## UAV THERMOGRAPHY

- UAV operations required on separate days to scan multiple corridors.
- Challenges faced due to weather variability.
- Flight days had similar but not identical temperature and UV index, potentially affecting surface temperature measurements.
- Time constraints limited scanning to a 1/2 mile by 1/8 mile corridor.
- Selected area for maximum variability in land use conditions.
- Small sample size means macro-scale data should not be generalized broadly unless land use is similarly configured.
- Area measurements by thermal classes suggest influence by surrounding urban conditions.
  - 75 North corridor: 53% of surfaces above 90°F, higher than Regency's 39%, attributed to less canopy coverage.
  - Gene Leahy Mall corridor: 72% of area above 90°F, likely due to highly urbanized context.
- UAV thermography can produce RGB and infrared digital surface models.
- Drone flights can be optimized for 3D thermography on oblique surfaces.
- Future studies should further examine the efficacy and applicability of these models.

## GROUND THERMOGRAPHY

SURFACE TEMP °F: 95.2  
HUMIDITY (%): 54.8  
HEAT INDEX °F: 100  
WET BULB GLOBE TEMP °F: 90

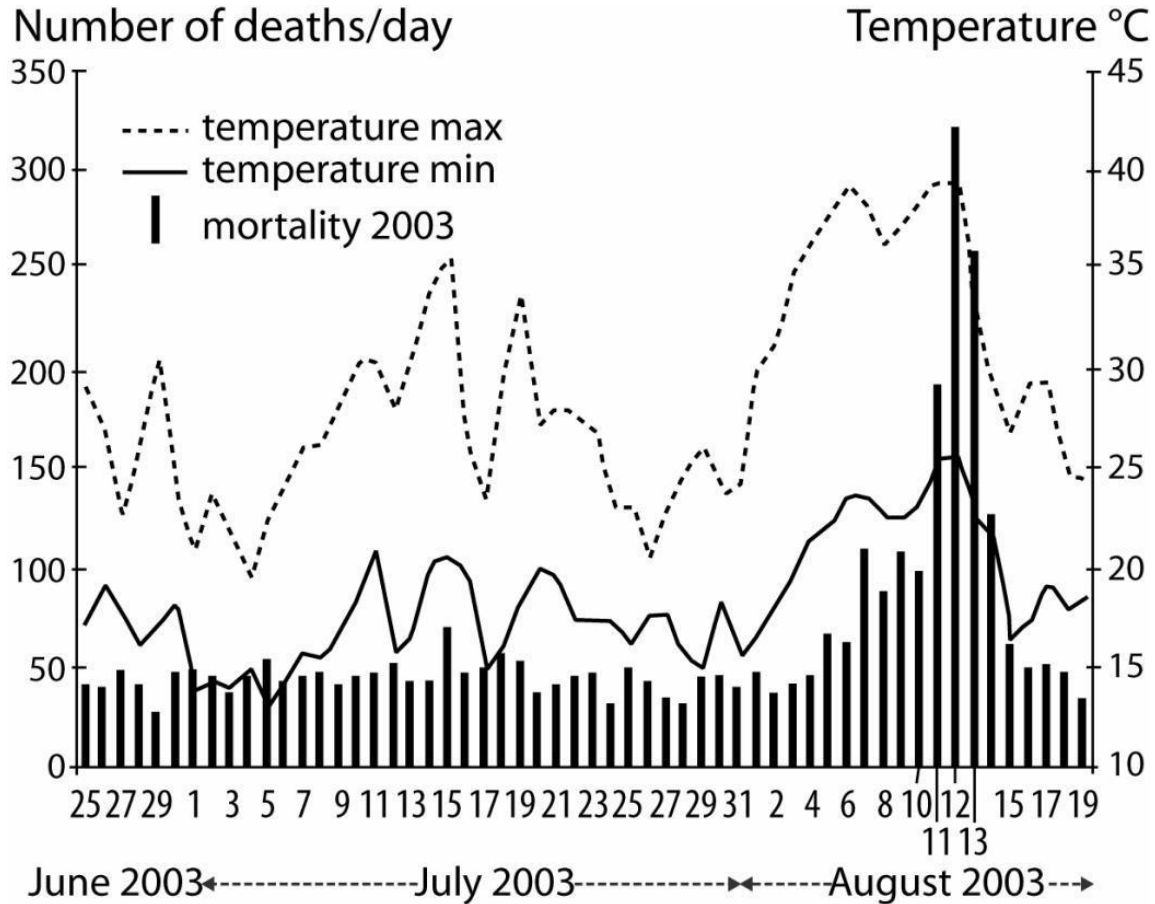
VEGETATION [SUN]: 82.6° F

CONCRETE [SHADE]: 99.3° F

METAL [SUN]: 89° F

CONCRETE [SUN]: 103.5° F

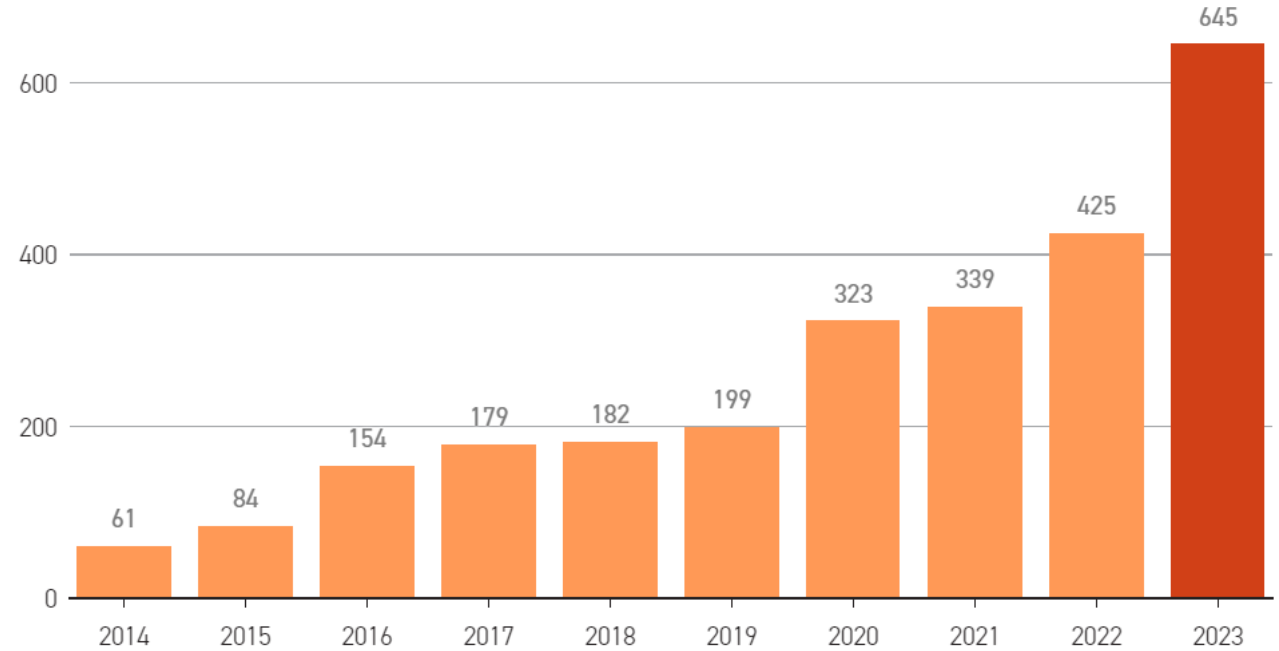
- Ground temperature fluctuations are influenced by changing weather conditions like cloud cover.
- Fluctuations stay within a reasonable standard deviation compared to infrared imagery.
- Time and weather constraints affect field work.
- A heat map from regularly spaced ground temperature measurements could validate UAV thermography data.
- Ground measurements were useful for spot checking aerial measurements.
- Future studies could benefit from more robust "ground-truthing."



Source: University of Hawaii at Manoa/Benedicte Dousset

## Deaths caused by heat in Maricopa County, Arizona have increased tenfold in the last decade

Number of heat deaths in Maricopa County, Arizona



Source: Maricopa County Department of Public Health



# INTRODUCING THE THERMAL TOOLKIT:

TECHNOLOGIES AND TECHNIQUES FOR VISUALIZING THERMAL DISPARITIES

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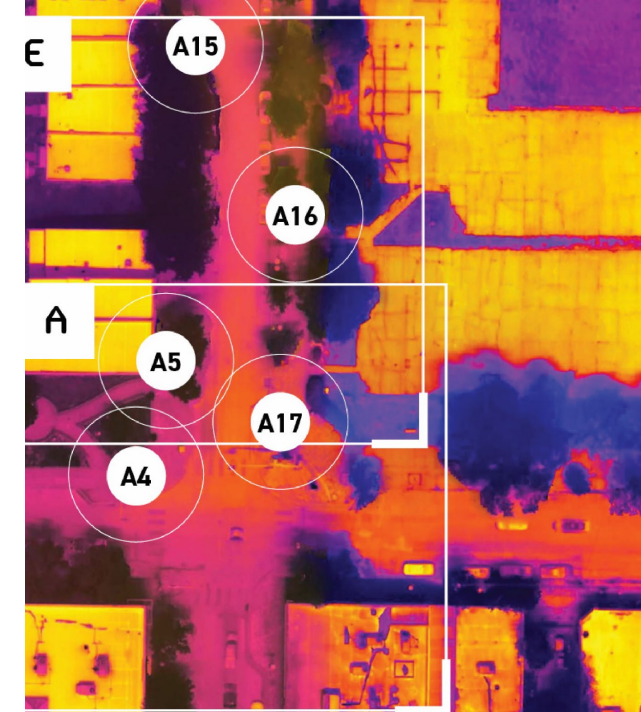
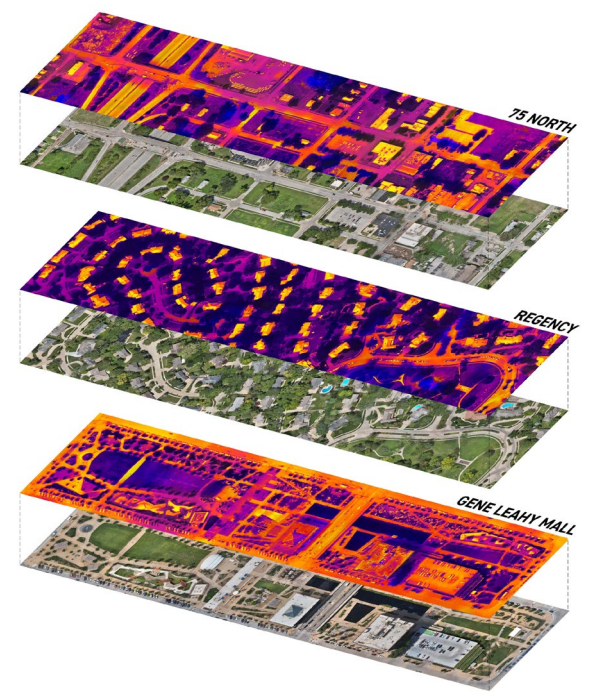
**KEENAN GIBBONS**, LEED, PLA, Landscape Architect – SmithGroup  
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2024 LAF WEBINAR



SALVADOR LINDQUIST

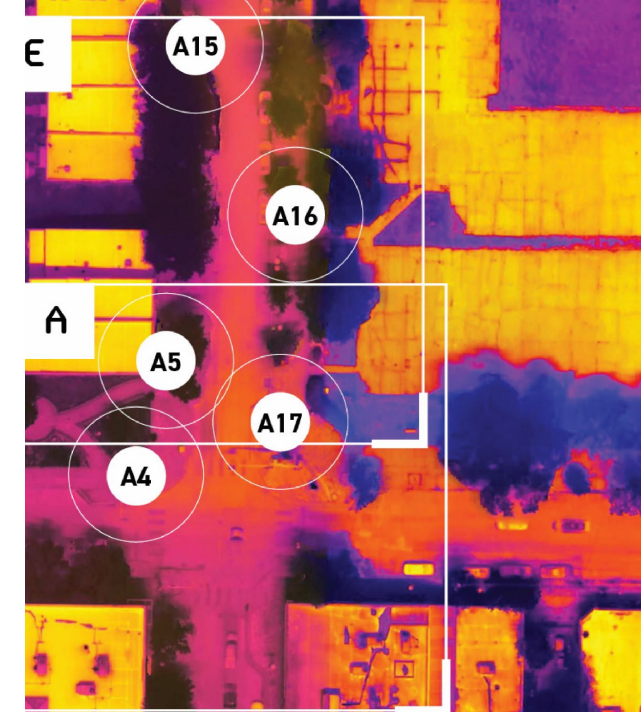
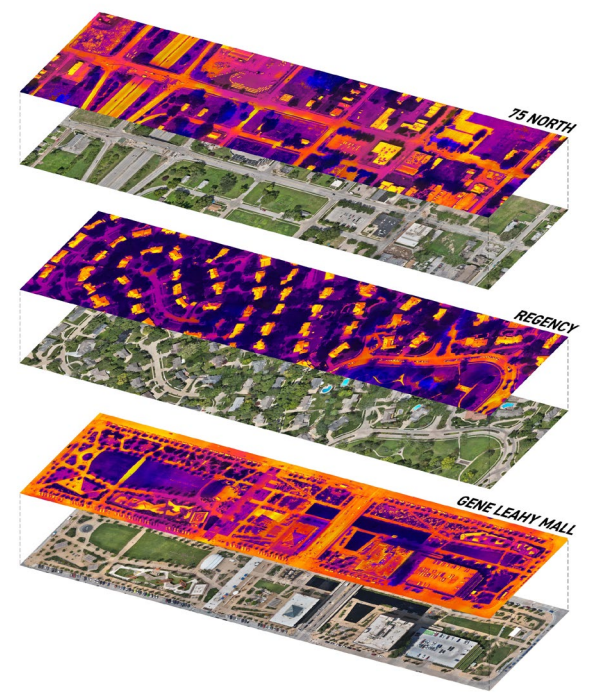
KEENAN GIBBONS



# VISUALIZING EXTREME HEAT DISPARITIES

AUDIENCE Q&A





# VISUALIZING EXTREME HEAT DISPARITIES

THANK YOU!

