Asset Management Using IoT- and GIS-Based Solutions

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P4 INFRASTRUCTURE

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Good morning everybody, my name is Joe Diekfuss with P4 Infrastructure. Today I'd like to talk about Asset Management Using IoT- and GIS-Based Solutions.

Presentation Outline

- Introduction to P4 Infrastructure
- Internet of Things and Internet of Infrastructure
- GIS Integration
- Examples using P4 Products
- Questions

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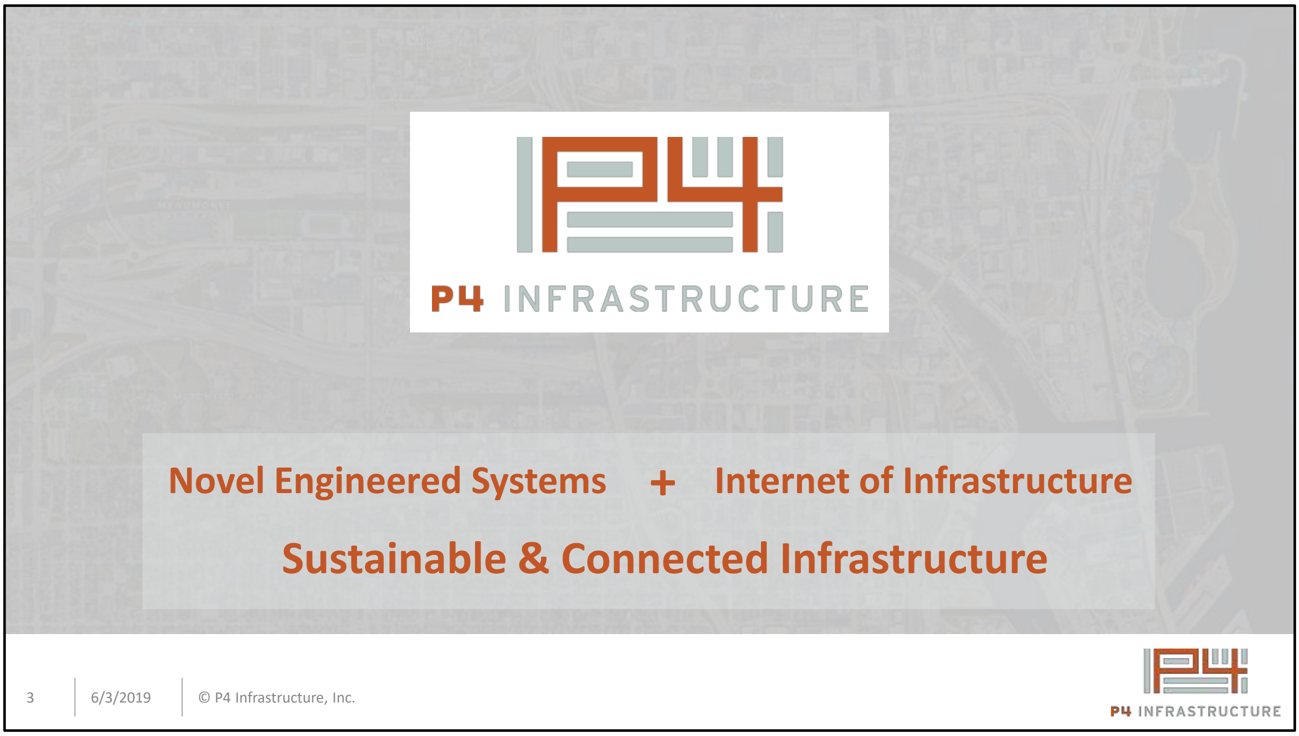
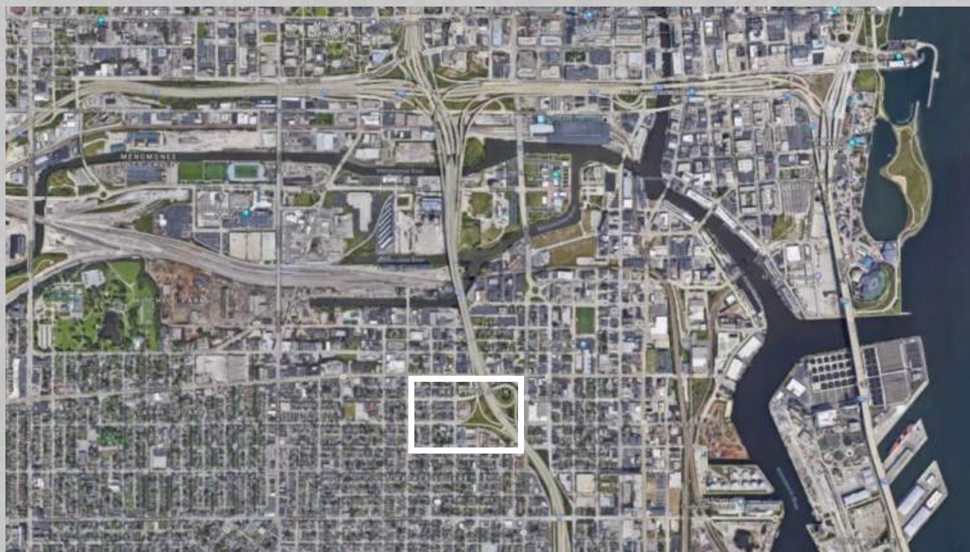


At P4 Infrastructure, we are combining civil, mechanical, and electrical engineering in pursuit of technology-driven products.

Our core focus is sustainable and connected infrastructure.

We'll get there by building novel engineered systems and the internet of infrastructure. I'll explain these in a couple of slides.

But in the end, we are changing the civil engineering industry by creating products capable of connecting us with our built environment.



Google Maps

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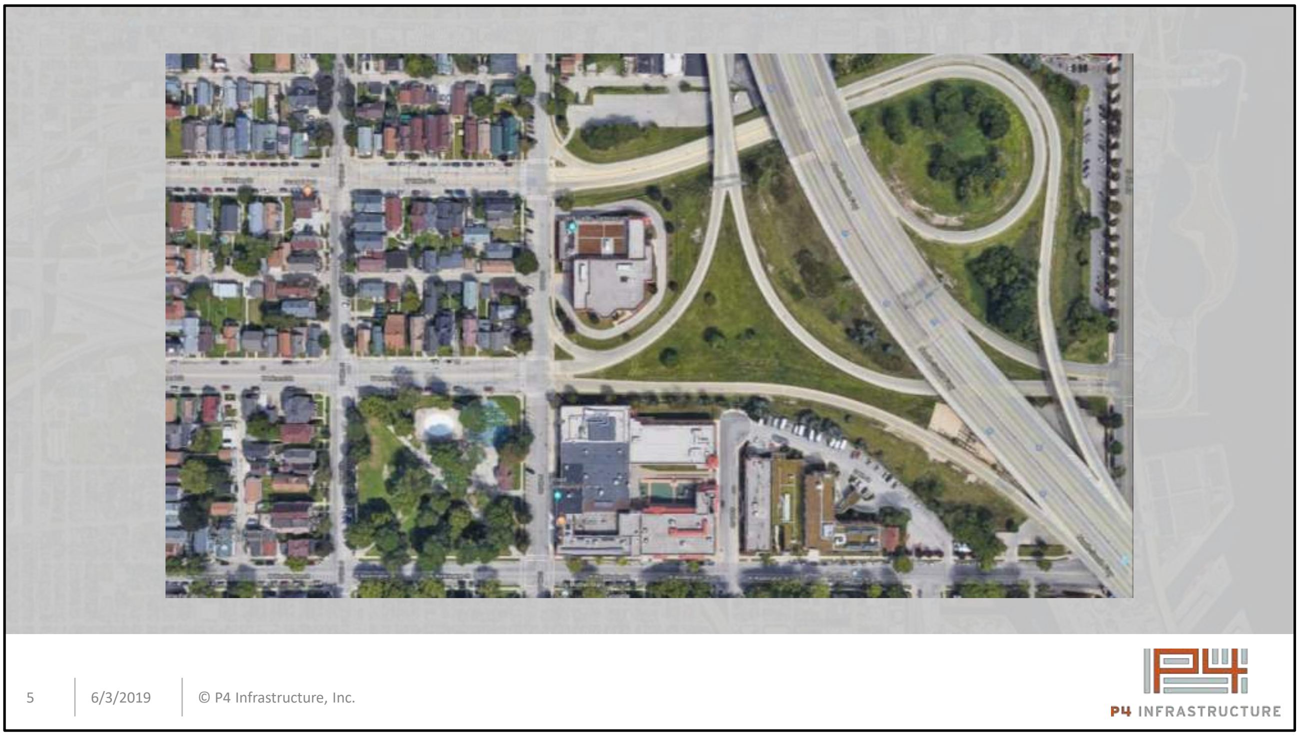
I want to start with a big picture view.

This is an aerial view of the City of Milwaukee, WI.

There is clearly a lot of infrastructure shown in this image.

Let’s zoom in on just one small portion.



Even in this zoomed-in-view of the previous image, there is an enormous amount of infrastructure.

Some of the assets include:

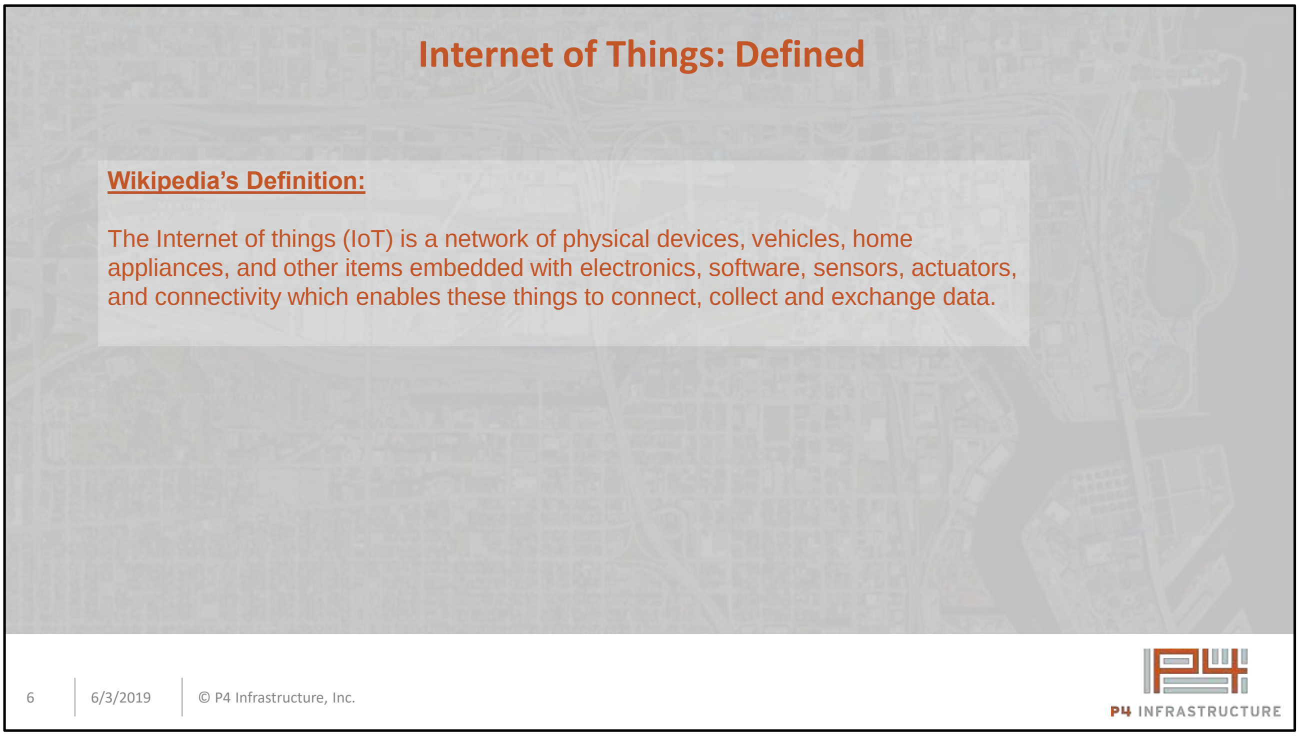
- traffic sign and signal support structures
- retaining wall systems
- bridge decks and bridge girders
- bridge foundation systems, and
- pavement structures.

And that's just what you can see.

Beneath the surface (and off-screen) infrastructure exists that you can't see, like:

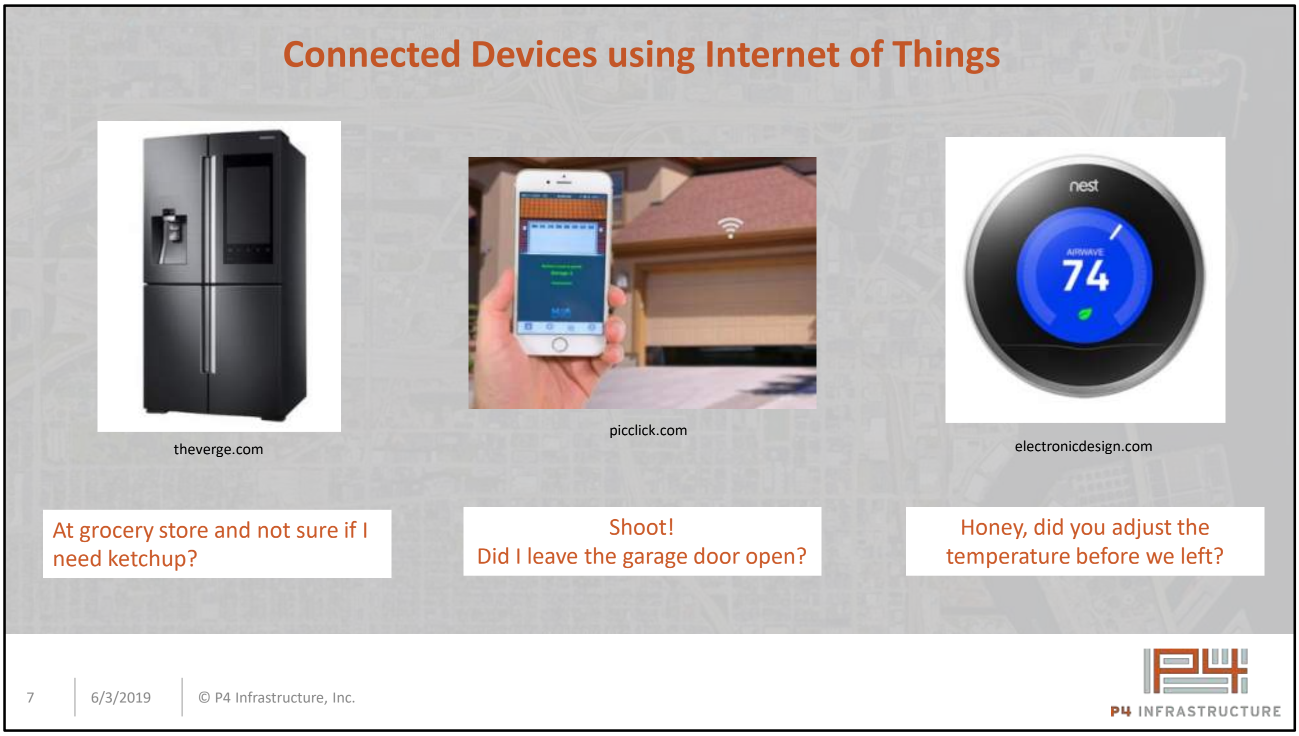
- water main and drinking water treatment facilities
- storm sewer systems
- sanitary sewer systems and wastewater treatment facilities

The question is: How do we design, construct, operate and maintain this level of infrastructure effectively? The answer: IoT. We are applying Internet of Things technology to the civil engineering industry to build the Internet of Infrastructure.



Now, many of you probably know what IoT technology is and some of you may actually be using IoT technology and just not know that that's what it's called. So I thought it would be a good idea to define it here so we're all on the same page.

Here is Wikipedia's definition. To put it simply, IoT is a network of connected devices. Things that weren't smart before, are now. By smart, I mean able to collect, receive or send data. The IoT allows devices to communicate directly with one another to exchange data.

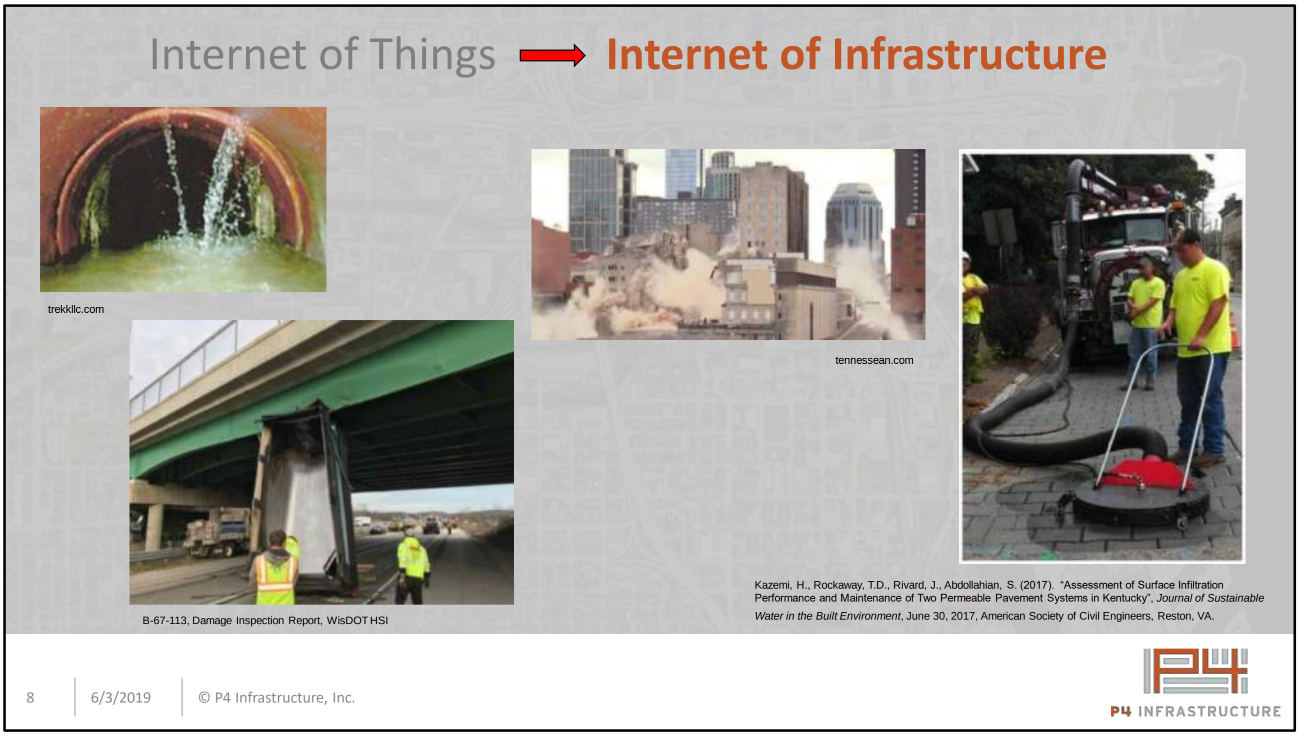


Right now, you can go to the store and buy:

fridge that can tell you what food is inside,

a garage door that can tell you whether it is open or closed,

And a thermostat that can automatically adjust the temperature in your home after it senses when you have left your property…

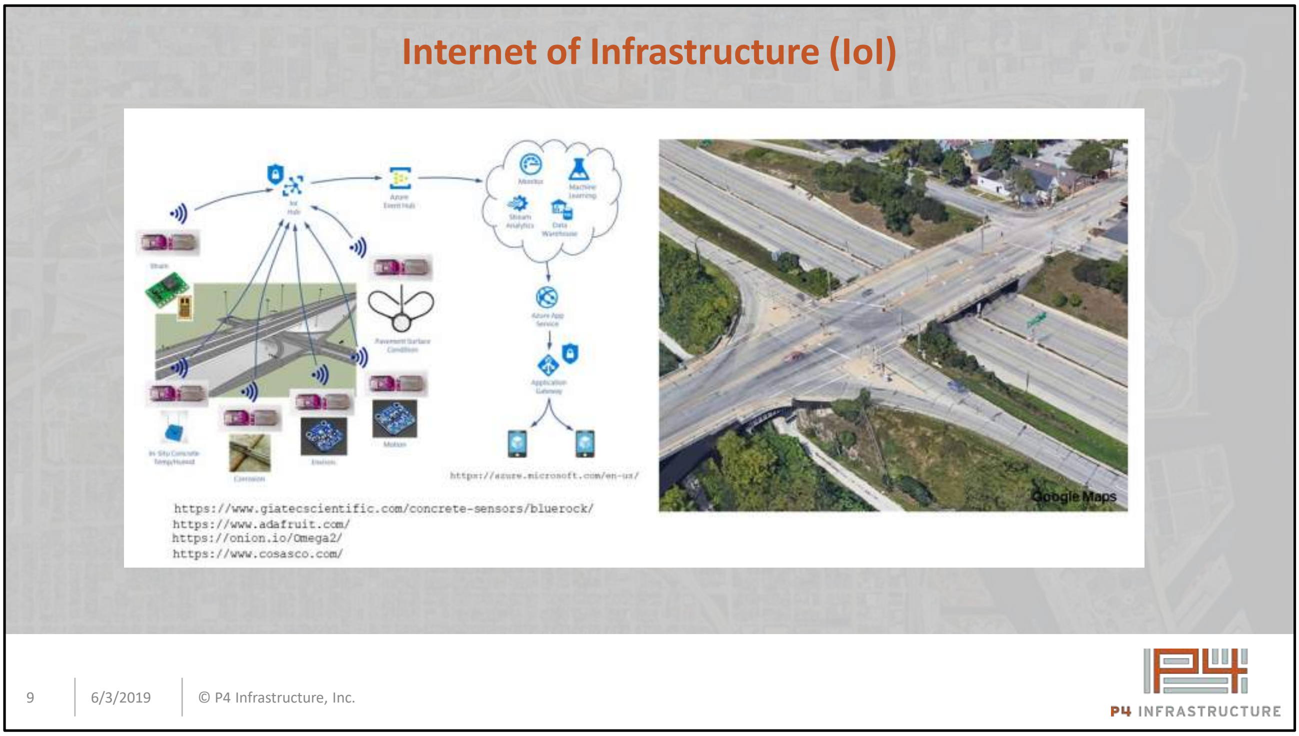


Then your sanitary sewer should be able to tell you when and where you have I&I.

Your bridge should be able to tell you when it has experienced a damaging load cycle or impact.

Your building… an excessive vibration.

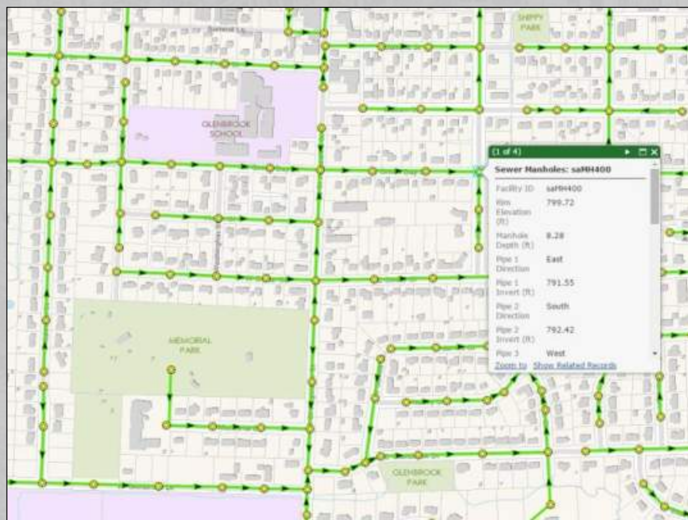
And your permeable pavement… it should be able to tell you when it's clogged.



If we can embed our infrastructure with devices that collect data and automatically pump that information to the cloud, that information can be used to inform decisions regarding design, construction, operation and maintenance of our infrastructure network.

This is the Internet of Infrastructure.

GIS Integration



www.releeinc.com – Robert E. Lee and Associates (website image)

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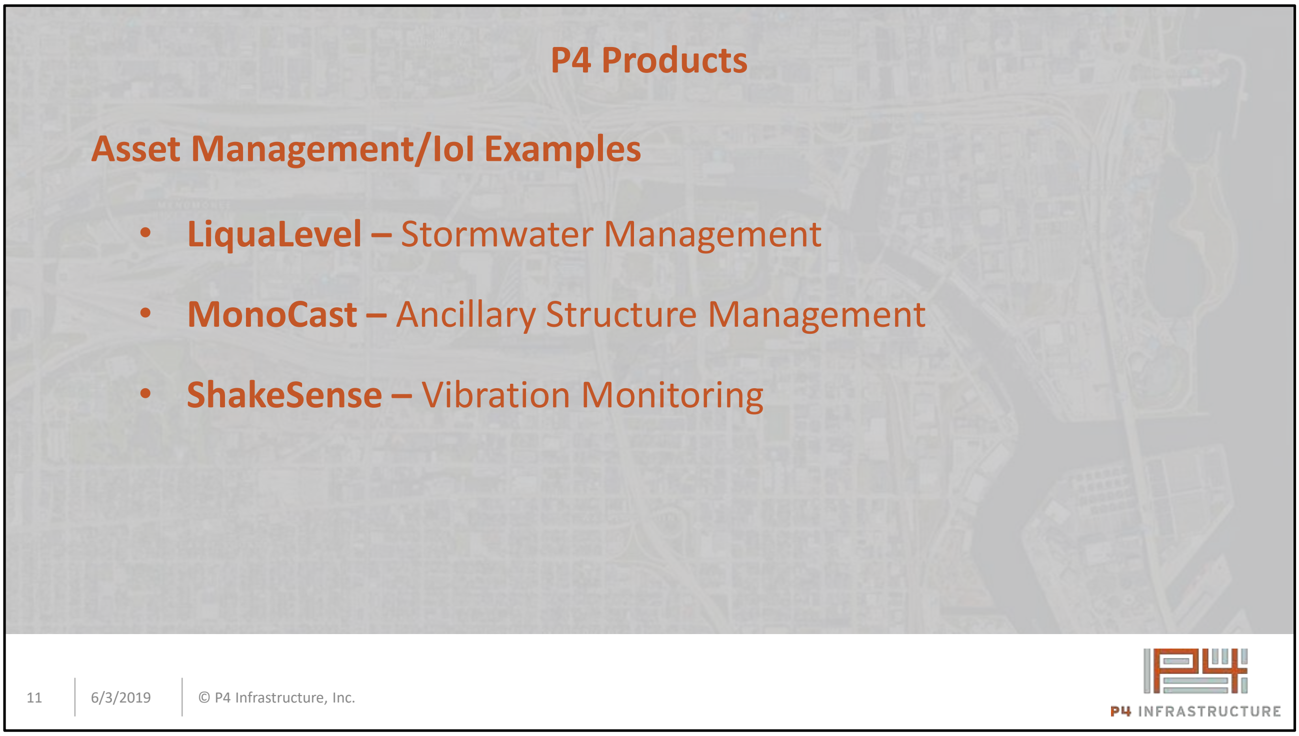
One question you might have is “how do I interface with the data?”

At P4, we have a data science consultant, with GIS experts, helping us develop the database structure and the data architecture required to overlay P4 sensor data on top of existing infrastructure layers.

Many of you are familiar with this sort of mapping interface, where you can turn on and off layers, click on features and query specific, static information, which is already a very powerful tool when it comes to asset management.

That’s why we’re developing our products to be able to integrate seamlessly within existing GIS platforms.



At this point, I'd like to walk through a series of specific examples involving civil infrastructure management where we incorporate P4 product solutions.

Our three flagship products are listed here.

Our products currently include: LiquaLevel, MonoCast, and ShakeSense. And please, by all means, stop by our booth and grab brochures for additional information and future reference.

Stormwater Management

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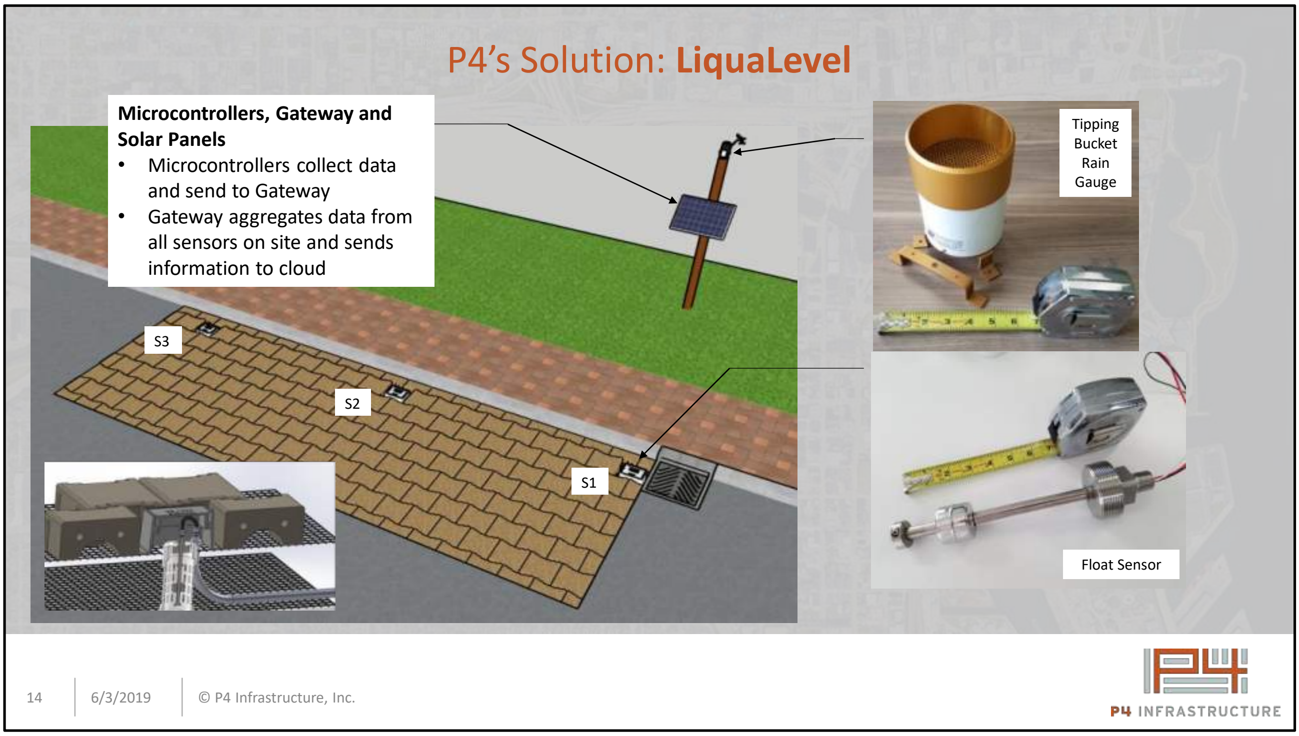
This first example involves stormwater management.

There are many ways to manage stormwater runoff to hopefully prevent issues like the ones shown on this slide.

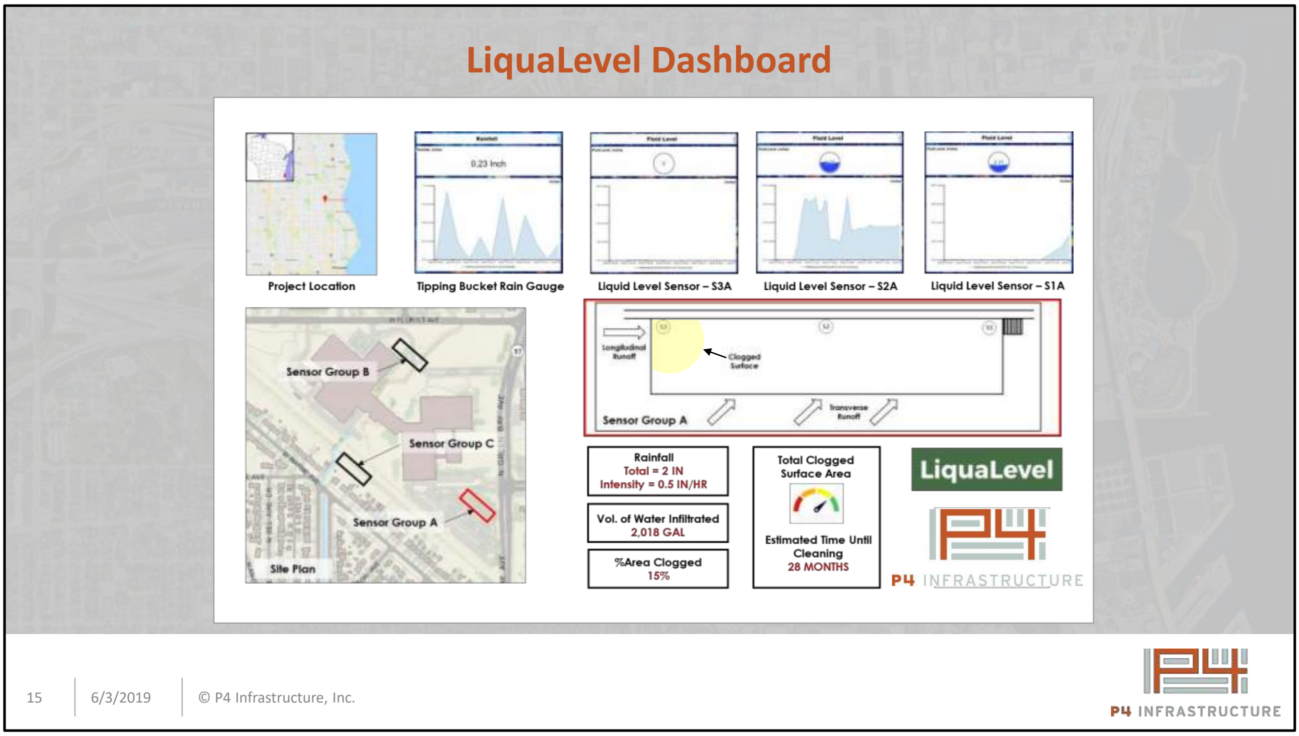
One such method and the one I'll focus on for this example is permeable pavement.



P4's solution to aid in stormwater management is LiquaLevel.

LiquaLevel is an IoT-based solution that autonomously measures rainfall using a tipping bucket rain gauge and resulting runoff in the form of water level using a float sensor. The water level being measured is in the aggregate storage layer underneath the permeable pavement surface.

LiquaLevel not only tells us how much water gets into a stormwater management system after a rain event, it also tells us how fast it got there and how long it stays there.



This is one way that users can interface with the data collected by LiquaLevel sensors. Permeable Pavement owners can view the data from each sensor and gain a better understanding of how their system is functioning throughout the service life of the asset. For example, they can get vital information like: When do I need to clean my pavement?

LiquaLevel enables ‘the novel permeable pavement engineered system’ to become part of the internet of infrastructure.

Ancillary Structure Management

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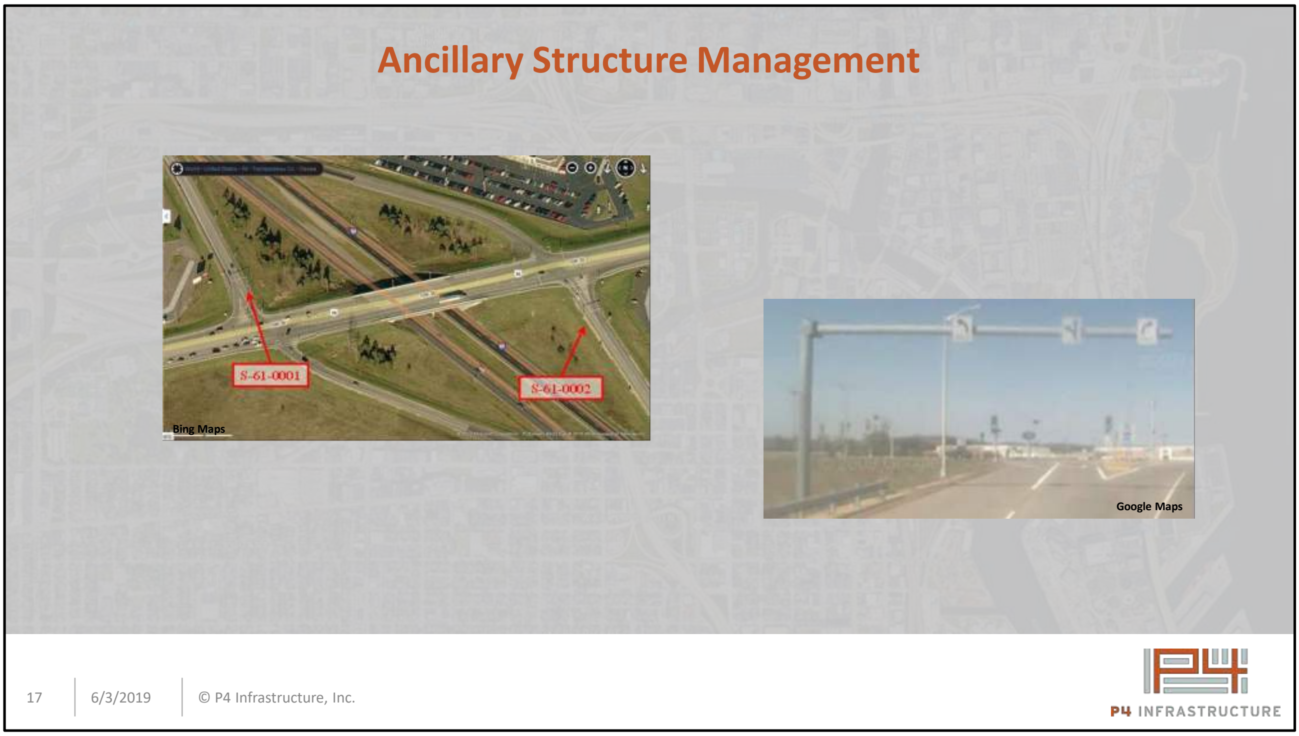
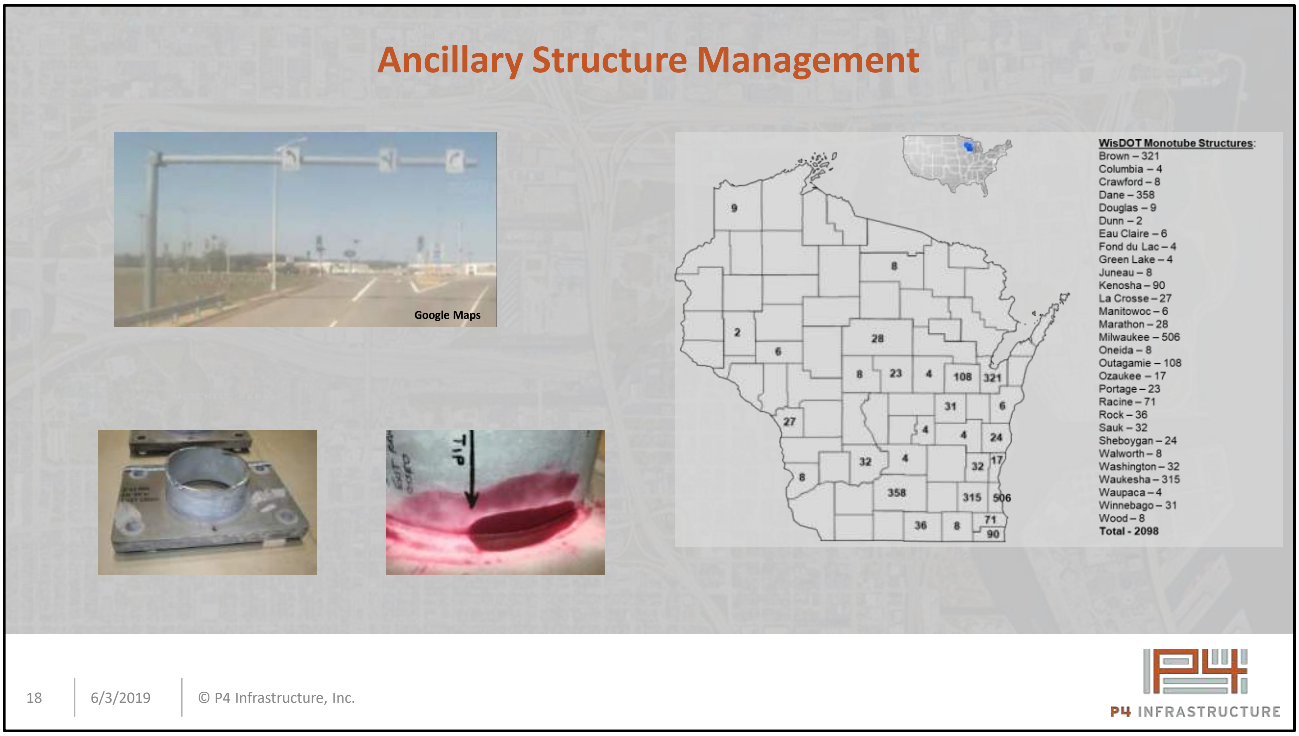


Our second example involves traffic signal and sign support structural systems, specifically the ones that use the monotubes.

In 2003, two sign structures, like the one shown on the right side of the screen were correctly designed and constructed according to national standards.

A 2007 inspection found them in good health.



Four years after that, one of the two structures had visible and significant structural damage and its sister structure had cracks unseen by the naked eye during inspections.

This means a severely damaged structure was supporting a nearly 2,000 lb. steel tube over three lanes of traffic for potentially four years.

Both structures were supposed to have infinite life.

TABLE 2-1 Documented excessive vibration and fatigue cracking of sign, signal, and light support structures

NCHRP Report 469

Location	Date	Failed Component(s)	Notes
AK	1994	Column base	High-mast luminaires
AR	?	Column base	Cracked fillet welds between baseplate and stiffener
		Truss connections	Cracked tube-to-tube welds
CA	1995	Column base	Failure of VMS after 18 months
			Loose/missing anchor rods
			Cracks around hand holes and baseplate detail
	1999	Column base	Failure from socket-weld cracking
CO	1994	Mast arm connection	Failures in 3 sign structures over 5 years old
CT	1996	Anchor bolt	Crack found during inspection
		Truss connection (Alum.)	Crack found during inspection
FL	1996	?	Excessive deflections on bridge support overhead VMS structure
	1997	Mast arm connections	15-m span signal support structure
GA	1994	Anchor bolt	Failed bridge support structure
ID	?	Truss connections (Alum.)	Tube-to-tube welds
IL	?	Mast arm connection	
KS	1997?	?	Failure of numerous signal structures
KY	?	Column base	Cracks found in fillet welds connecting stiffener
		Truss connections (Alum.)	50 cracked tube-to-tube welds
LA	?	Anchor rods	Found to be loose/missing
MD	?	High-mast luminaires	Weathering steel
MI	1990	Anchor rods	Failure of 2 sign structures with truss-type mast arms; others found loose/missing
	?	Mast arm connection	Cracks in pipe wall at weld termination
	?	Truss connections	Cracks in pipe wall near tube-to-tube weld
MN	1999	Handhole	Crack found near handhole
MO	1996	Mast arm connection	Failures of several signal support structures
NE	?	Monotube signs	
NV	1996	?	Failure of VMS structure
NH	1993?	Truss connections (Alum.)	Found many cracks during inspection (Fig 2-1)
NJ	1995	?	Excessive deflections on VMS
		Column base	Failures of light poles
NM	1992	Column base	Failure of VMS socket joint after only a few weeks
	?	Anchor rods	Found to be loose/missing
	?	Hand hole	Cracking discovered
NY	?	Anchor rods	Found to be loose
		Hand hole	Cracks discovered
NC	?	Anchor rods	Found to be loose/missing
ND	1998	?	Excessive vibration of 15-m span signal
OR	1993	Column base	Failure of 25% of 160 straight square light poles in 6 months
TX		?	Excessive vibration of signal poles
		Anchor rods	Found to be loose/missing
VA	1993	Column base, Anchor rods	Cantilevered variable message sign
	1996	?	Cantilevered variable message sign
	?	Truss connections	Cracked tube-to-tube welds
	?	Anchor rods	Found to be loose
WA	?	Anchor rods	Found loose or missing in cantilever sign structures
		Truss connections	Cracked welds at ends of diagonals
WV	?	Anchor rods	Found cracked/loose/missing during inspection
	?	Column base and mast arm connections	Cracks found at toe of groove weld, toe of fillet weld in socket joint, and fillet weld of stiffener, broken U-bolts
WI	1997	Numerous	See discussion in text
WY	1995	Mast arm connection	Cracks in 30% of signal structures inspected
		Anchor rods	Found to be loose/missing

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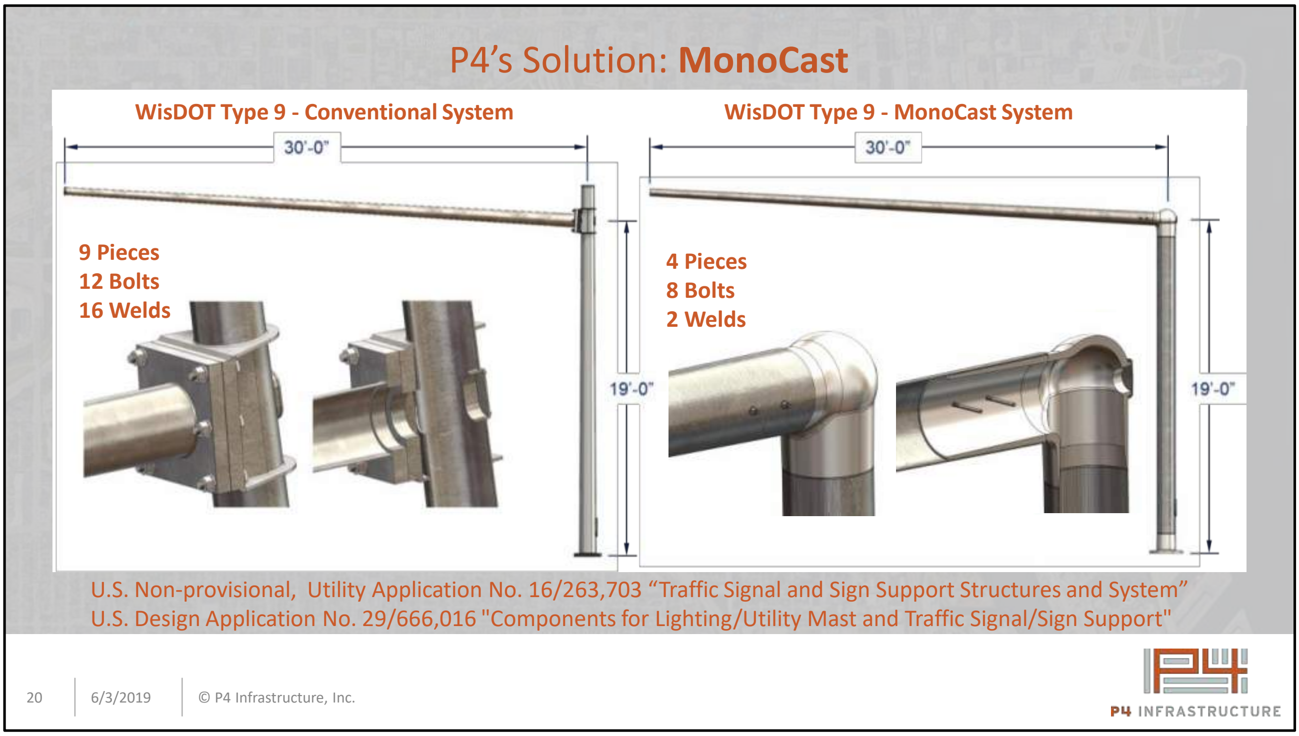
This is not just a WI problem either. This table is taken from a NCHRP Report indicating the issues experienced by 30 other states, ranging from cracked fillet welds to excessive vibrations.

It is interesting to note that WI is the only entry in this table that lists “NUMEROUS” in the failed component column… WI has had their fair share of issues with these structures which has prompted a number of research efforts through the years.

A better solution is needed.



P4's patent-pending solution is called MonoCast: Monotube structures utilizing steel castings.

The MonoCast System simplifies fabrication and assembly, lowers construction time, decreases life cycle costs, and eliminates the need for recurring field inspections at the arm to pole connection.

MonoCast will also be an IoT-connected system making it a part of the Internet of Infrastructure.

Retrofit options are available to extend service lives of existing structures and MonoCast satisfies all requirements of the latest AASHTO LRFD Specifications.

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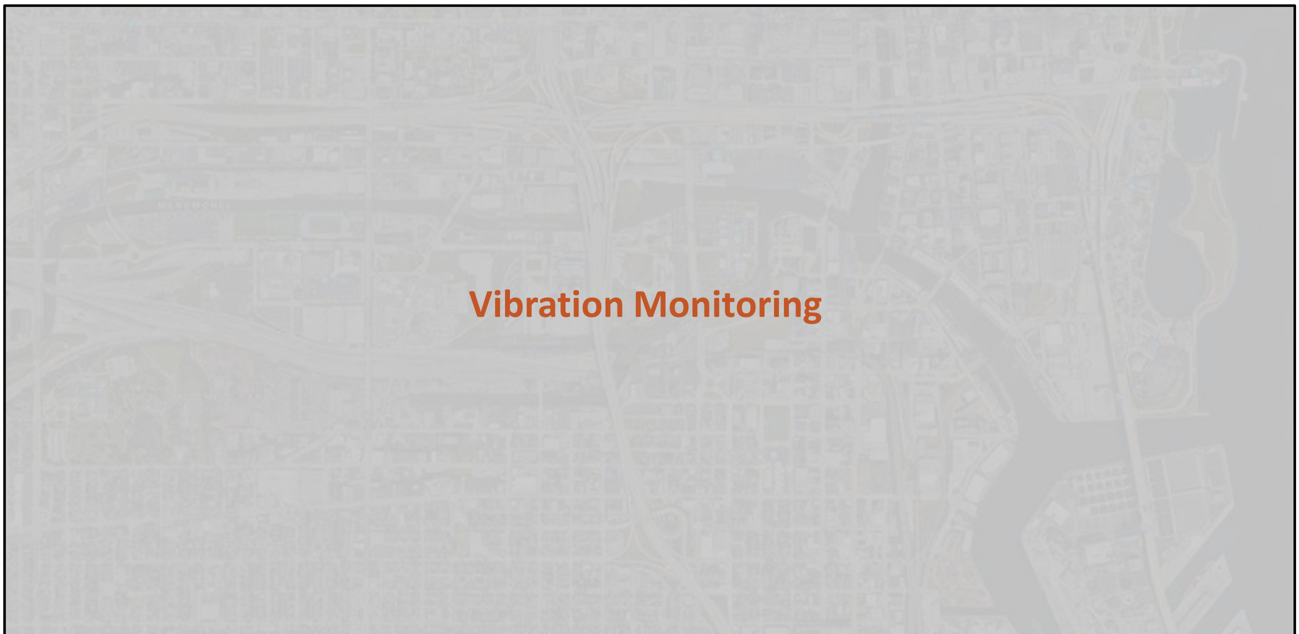

Vibration Monitoring

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Construction involving both building and road infrastructure systems also cause vibrations to the surrounding structures and property.

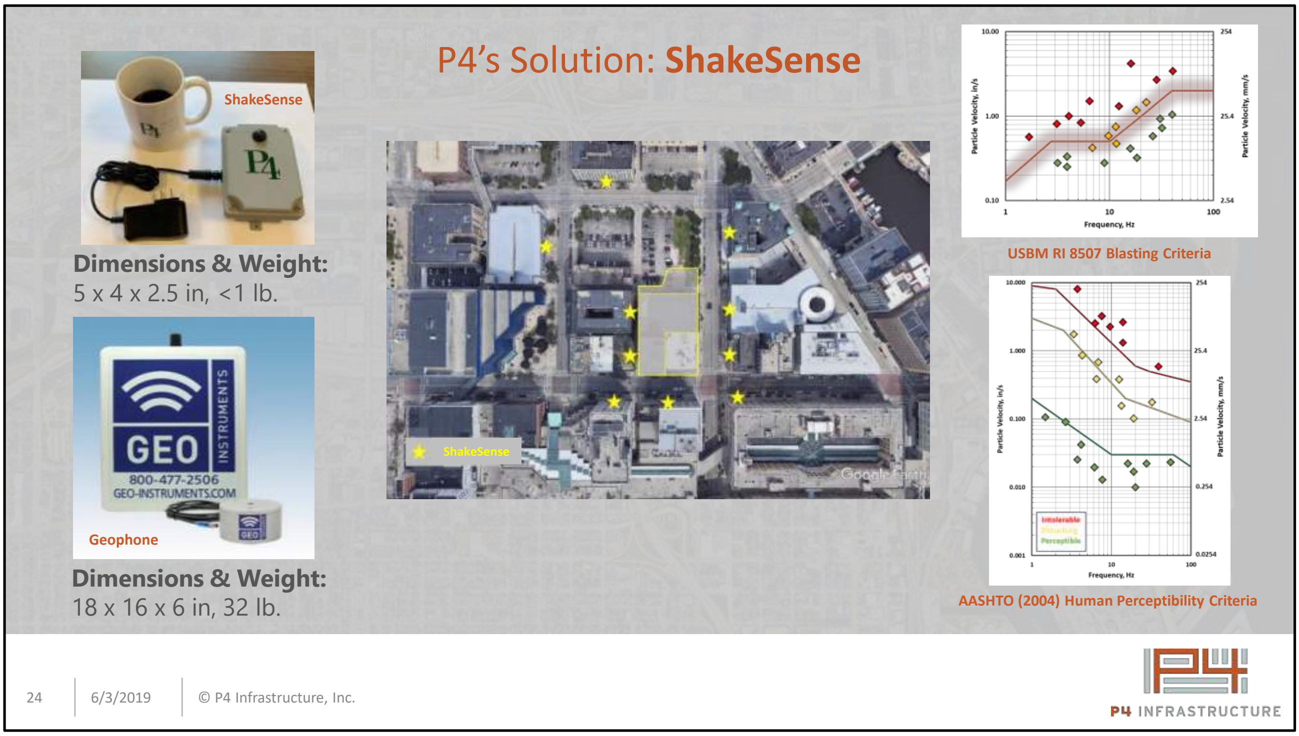
Vibrations in urban environments have the potential to damage historic buildings and their contents, disrupt modern healthcare facilities, and annoy large numbers of residents.

Monitoring construction vibrations is surprisingly expensive.

It is not executed in many projects because the “cost to measure” exceeds insurance deductibles.

Measured data would:

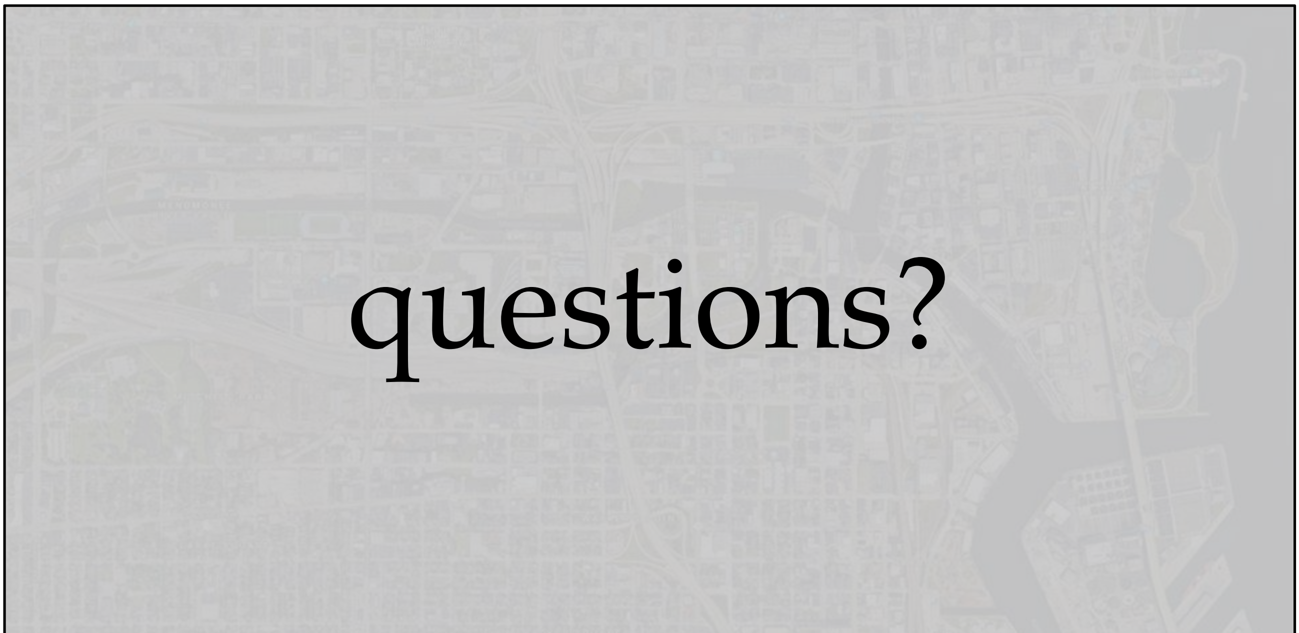
- support or disprove insurance claims,
- help the construction industry better understand methods and tendency for damage and annoyance,
- And help the insurance industry underwrite construction and homeowner’s insurance policies.



P4's solution for vibration monitoring is called ShakeSense. ShakeSense is a low-cost, small form factor, vibration monitoring system for evaluation of structural damage, nonstructural damage, and human perception of vibrations.

ShakeSense utilizes a highly sensitive, 3-axis, low-noise, low-drift accelerometer and a microcontroller with edge computing capabilities including Fast Fourier Transforms, Omega Arithmetic, and peak particle velocity vs. frequency spectra.

ShakeSense communicates via WiFi, LoRa or Cellular wireless connectivity



questions?

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