2020 embedded VISION summit®

Safer and More Efficient Intersections with Computer Vision

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Cubic Transportation Systems // **GRIDSMART**
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Who is GRIDSMART?

GRIDSMART, acquired by Cubic in January 2019, operates in the Intelligent Transportation Systems (ITS) space.

Cubic Transportation Systems is the leading integrator of payment and information solutions and services for transit, with 35+ million passengers served by Cubic systems daily.

GRIDSMART Technologies, Inc. began life as a venture-backed startup in Knoxville, Tennessee. Operations began in late 2007, product development in early 2008, and commercial availability in 2010.

GRIDSMART products are in ~8,000 intersections and ~1,300 communities, including 49 U.S. states and 29 countries. GRIDSMART products impact the lives of ~80 million people per day.

What is the GRIDSMART System product?

GRIDSMART is a unique system for <u>*intersection actuation*</u>*, traffic data collection, and situational awareness.*

Why *unique*?

Principles, Technology, Vision

Principles:

Simple. Flexible. Transparent.

Vision:

Improve The Lives Of One Billion People

What is *intersection actuation*?

Lights change in response to cars, not just timing.

Intersections 101 (N. America)

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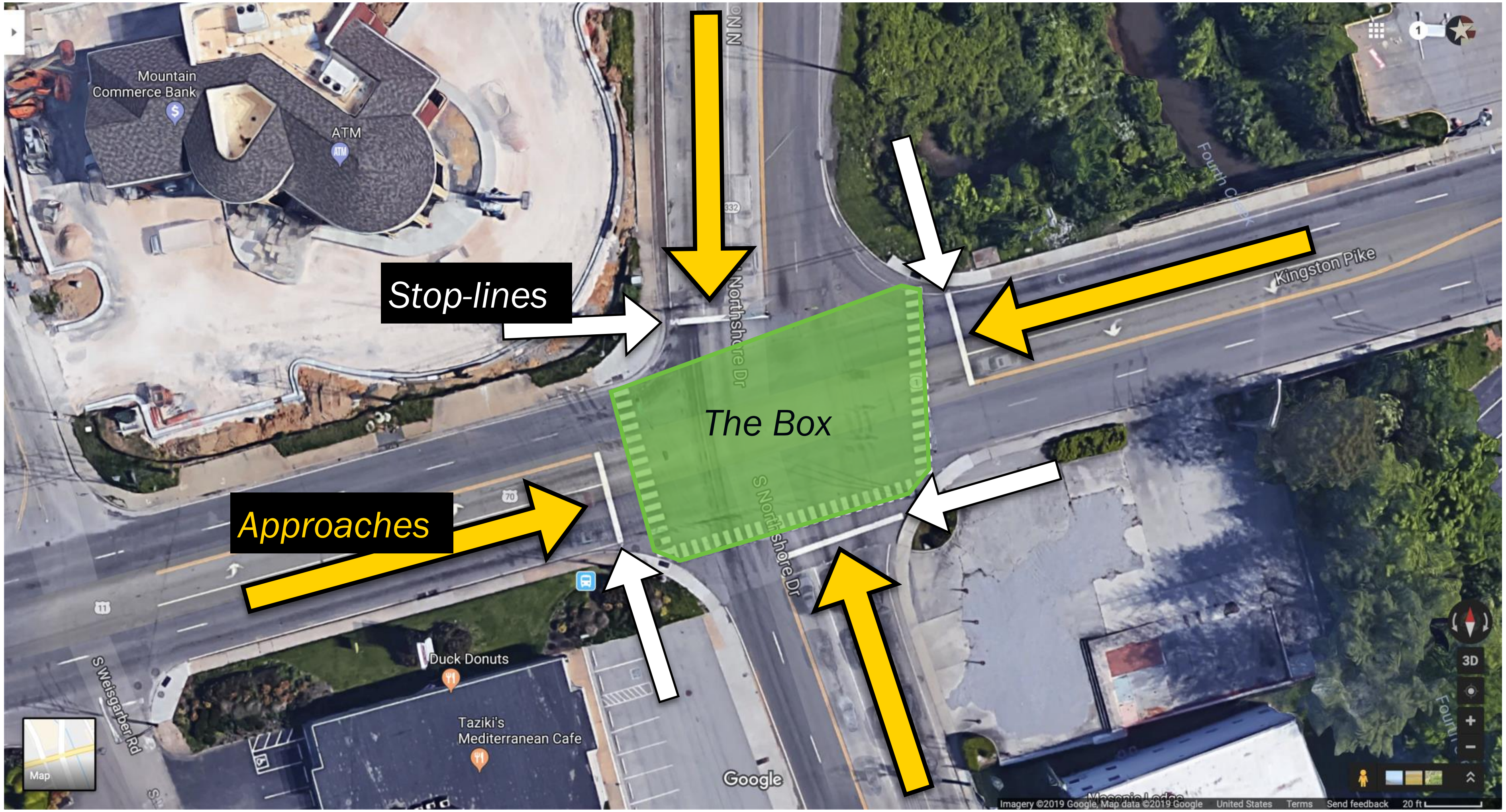
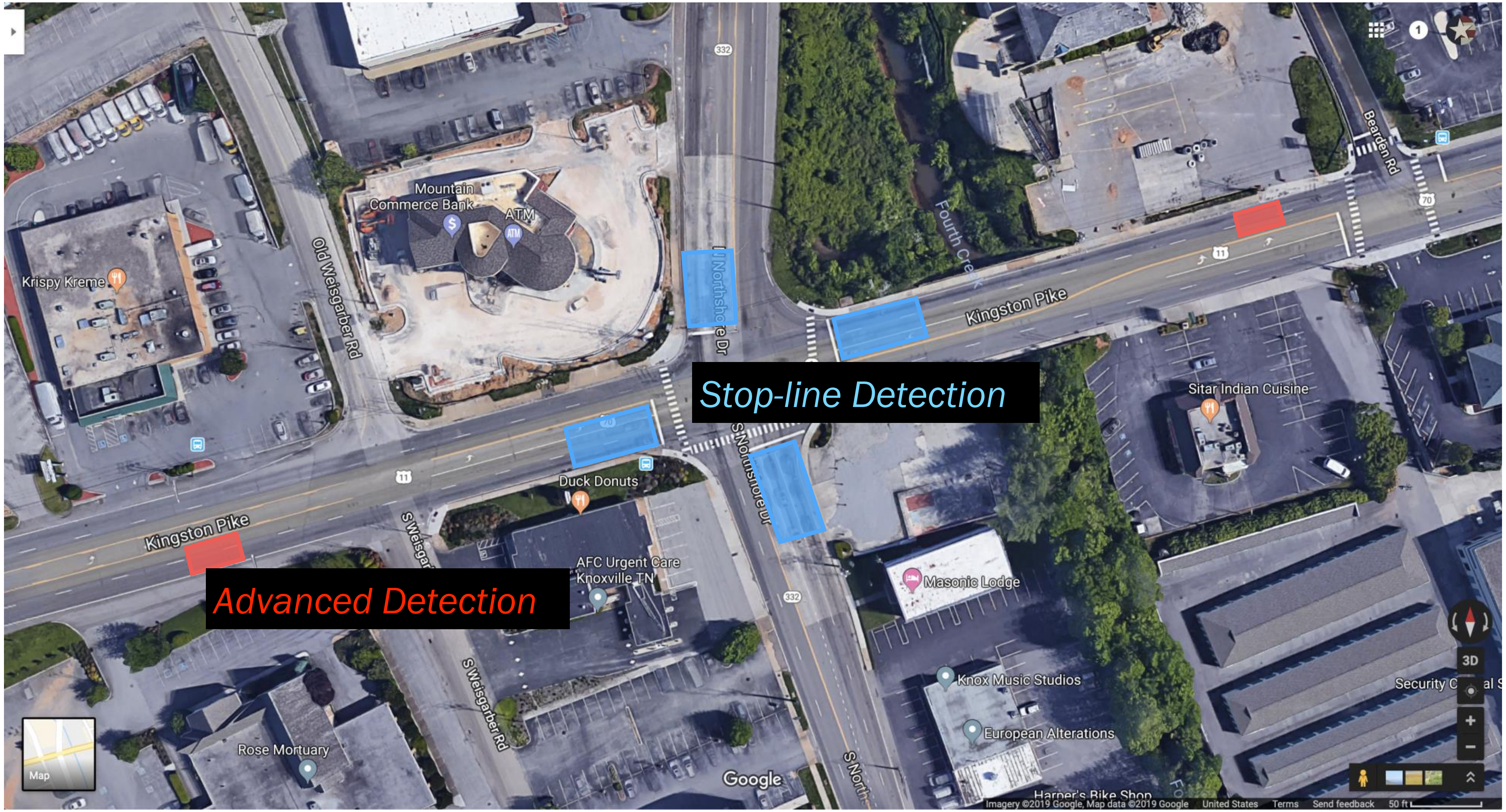
Intersections 101: Basic definitions

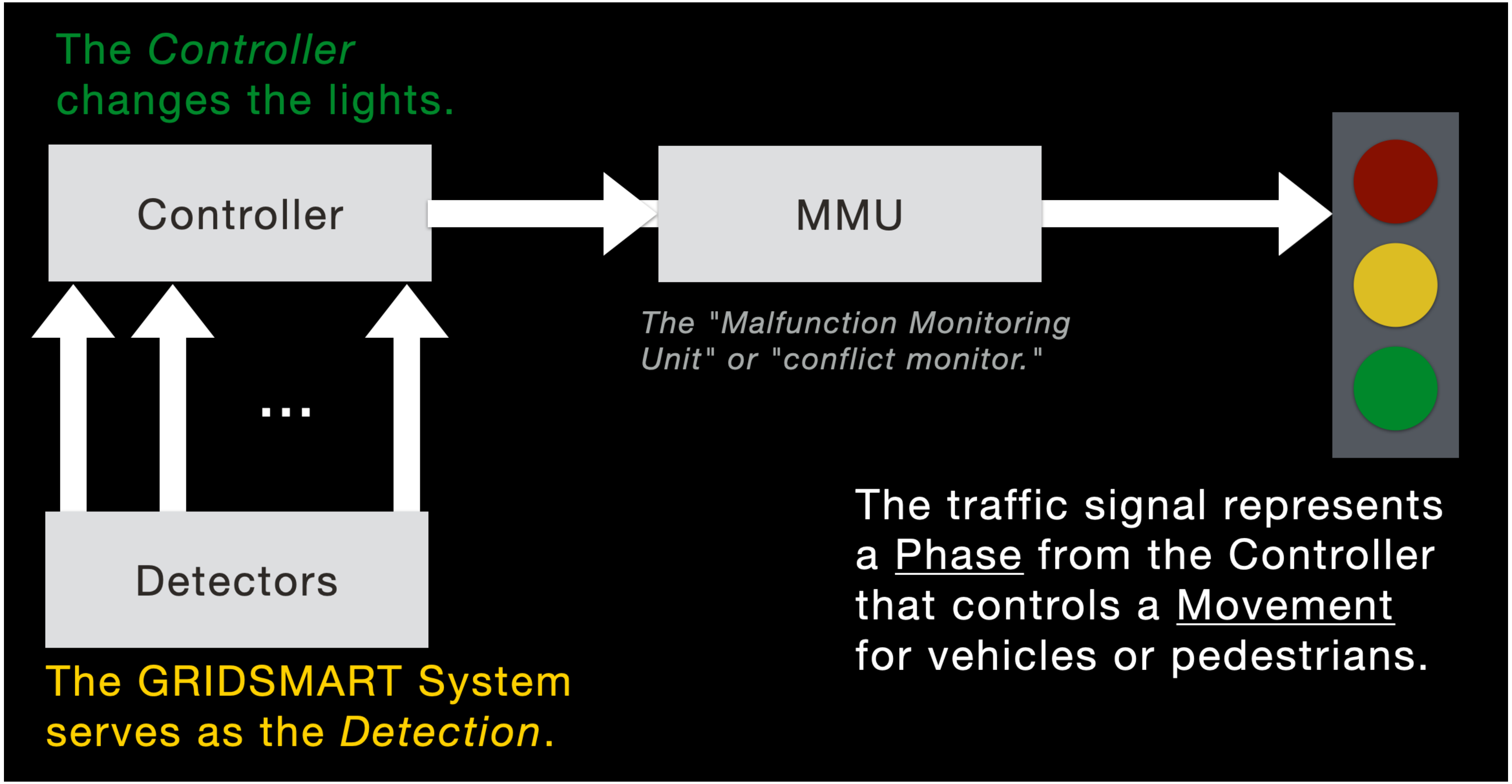


Intersections 101: Detection areas



Intersections 101: The cabinet

Intersections 101: How they work

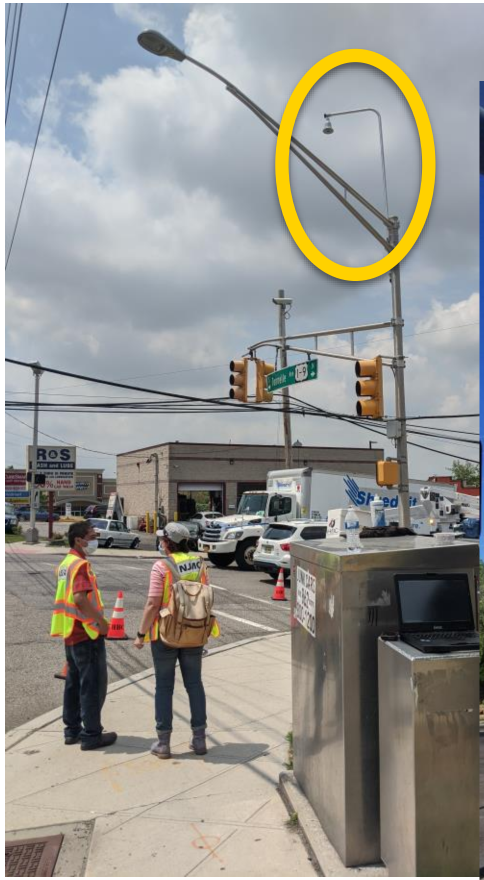


Intersections 101: Inductive loops for detection

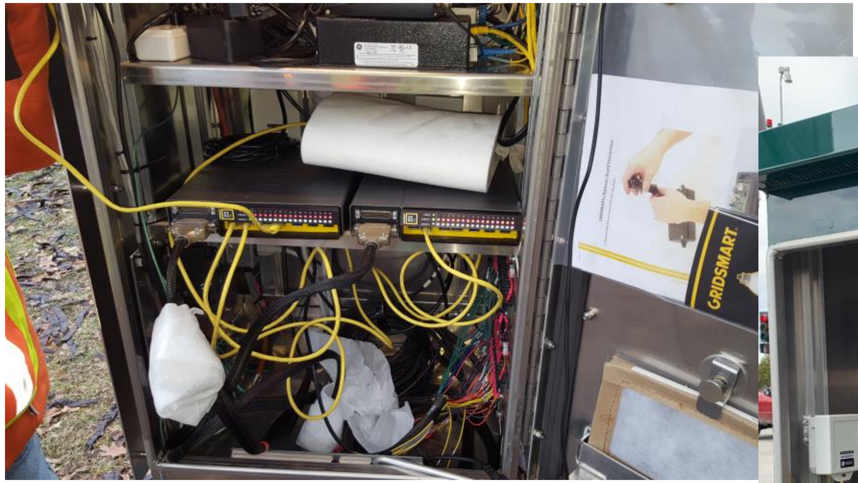
In-ground detection comprises about 55% of the detection market, down from about 70% in 2008. There are also wireless in-ground sensors (magnetometers), e.g. PODs, which work on the same principles.

Intersections 101: Above-ground detection

Other above-ground (directional) detection modalities include radar, traditional video, and thermal imaging. GRIDSMART was the world's first omnidirectional imaging system until copied by a competitor in ~2018.



Intersections 101: Inside the cabinet



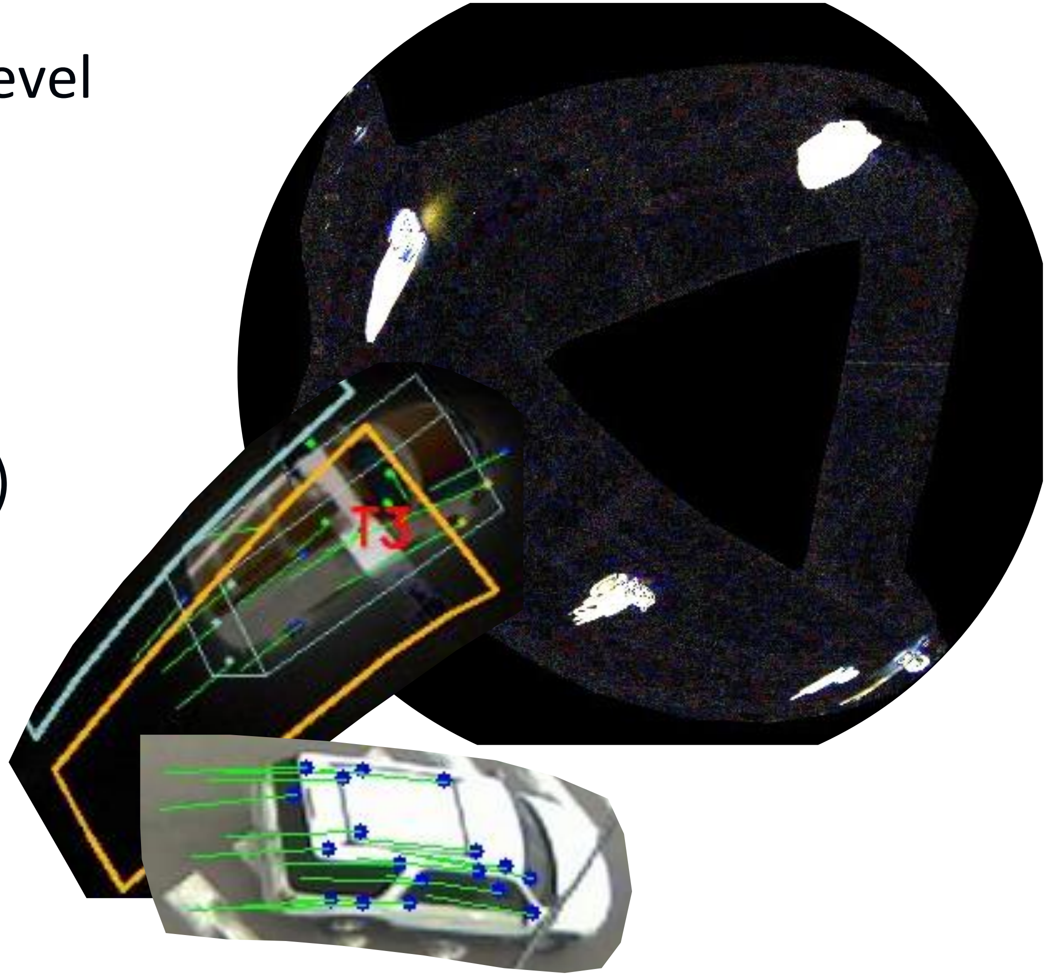
How GRIDSMART Works

GRIDSMART® Client 6.9 - Cherahala & Hardin Valley

How GRIDSMART works

A fusion of low-level image processing and high-level computer vision.

- Background & foreground modeling
- Salient point detection & tracking (optical flow)
- 3D inference (approximate extrinsic calibration)
- Bayesian hypothesis tracking
- Domain knowledge
- All processed in fisheye directly



Very early example, ~2009.

Showing greedy hypotheses. Note the bicyclist.

Bicycles:
Safer & More Efficient

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Bicycles: The Problem

- The State of California legislated (~2015) that bicycles receive longer *clearance intervals* than cars.

$$G_{min} + Y + R_{clr} \geq 6sec + \frac{(W + 6ft)}{14.7\,ft/sec}$$

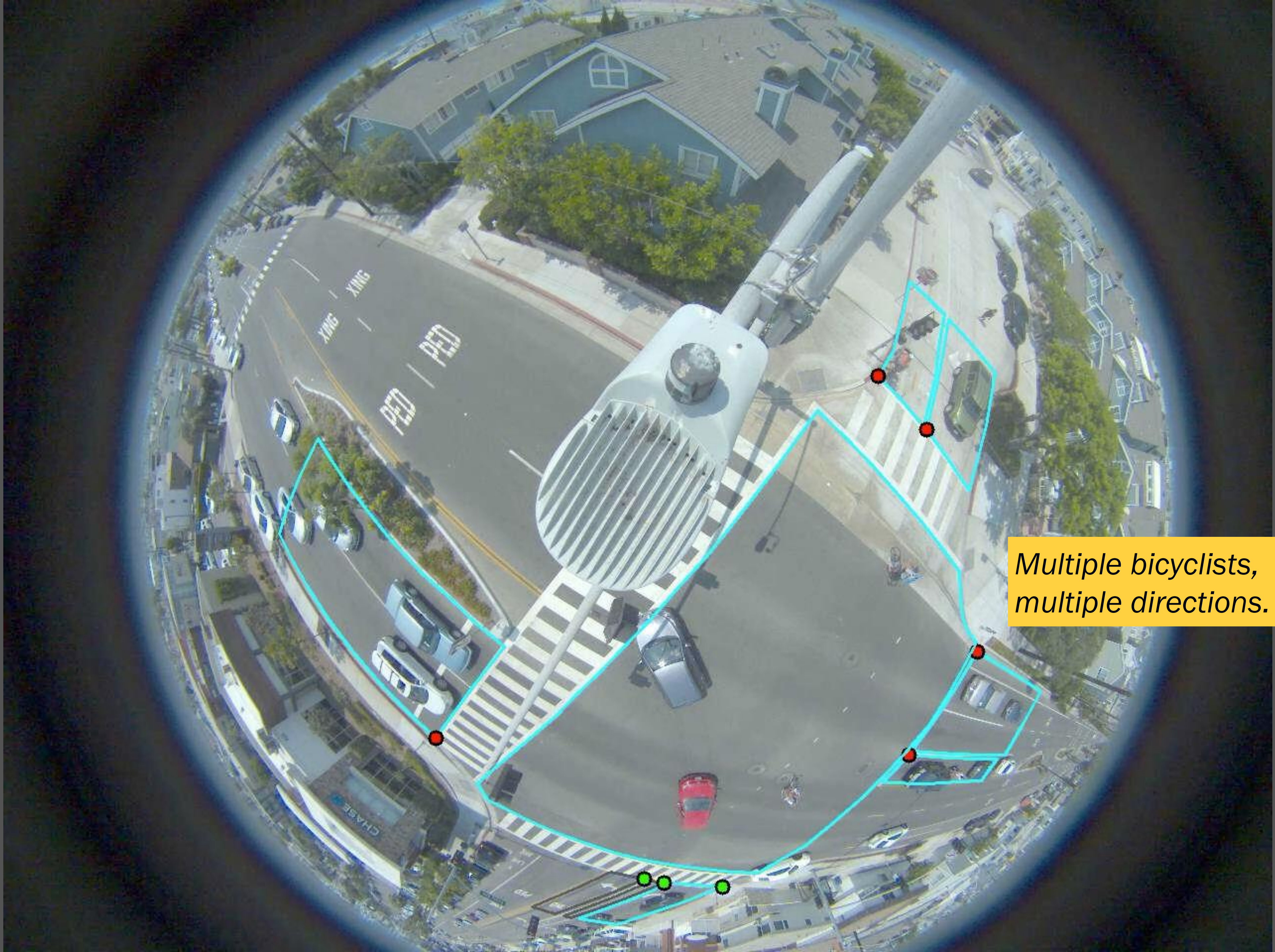
- That CA code was written to require bicycles be discriminated at the stop-lines or to require all signals be reprogrammed to provide bike clearances by default.
- There are both safety and efficiency problems with stop-line discrimination. GRIDSMART elected to not provide a solution, because we knew it was a stop-gap, unsafe, and suboptimal.
- The CA code changed (March 2018) to allow systems that provided adequate clearance, not requiring stop-line discrimination.
- GRIDSMART released its solution in 2019.

Bicycles: The GRIDSMART Solution

- Detect and track all moving objects.
- As those objects enter *the box*, continually apply a CNN image classifier.
- If object is possibly a Vulnerable Road User (VRU), activate output to controller. The controller will use that input to create short *green extensions* while a VRU is in the box.
- Continue to do inference until certainty, or object has left the box.
- We use Intel® Technologies' OpenVINO™ for inference on the CPU.

GRIDSMART is an Affiliate Member of the Intel Internet of Things Solutions Alliance. From modular components to market-ready systems, Intel and the 800+ global member companies of the Intel Internet of Things Solutions Alliance provide scalable, interoperable solutions that accelerate deployment of intelligent devices and end-to-end analytics. Close collaboration with Intel and each other enable Alliance members to innovate with the latest technologies, helping developers deliver first-in-market solutions. Learn more at : intel.com/iotsolutionsalliance.

Single bicyclist example.



Multiple bicyclists, multiple directions.

Multiple VRUs, inference until certainty (black dot).

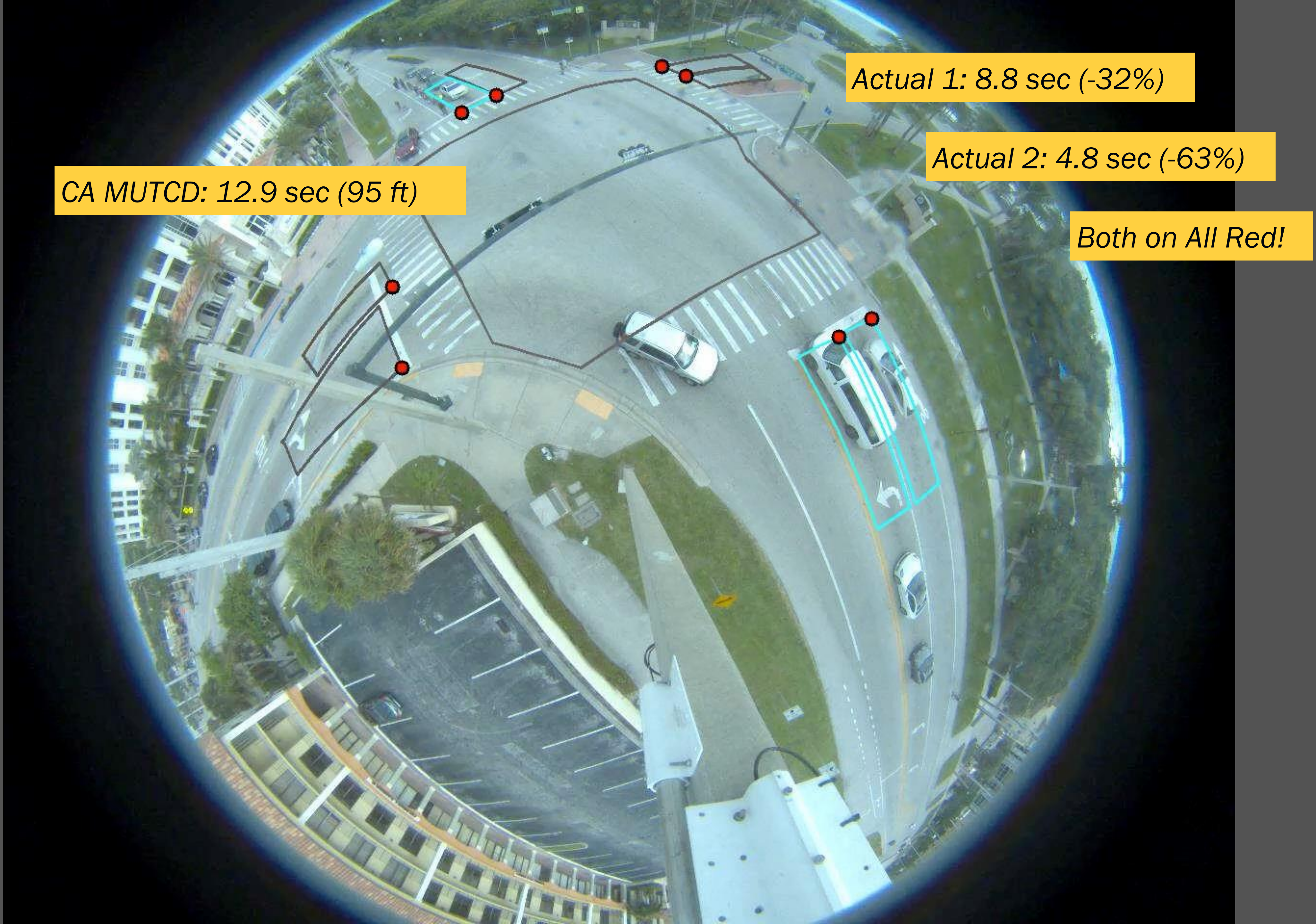
Why both safer & more efficient?

What if stop-line discrimination is not 100% accurate?

- A false positive means a long min green and a signifiant loss of efficiency.
- A false negative is dangerous because cyclist expects adequate clearance and is unaware they will not have it.

But in the box:

- A false positive triggers only a short extension. So inference in the box can err on the side of safety to dramatically reduce missed bikes while still being more efficient.
- Stop-line discrimination assume all bicyclists travel the same speed. Even if stop-line discrimination was 100% accurate, it still wastes green time.



Actual 1: 8.8 sec (-32%)
Actual 2: 4.8 sec (-63%)
CA MUTCD: 12.9 sec (95 ft)
Both on All Red!

Other Challenges

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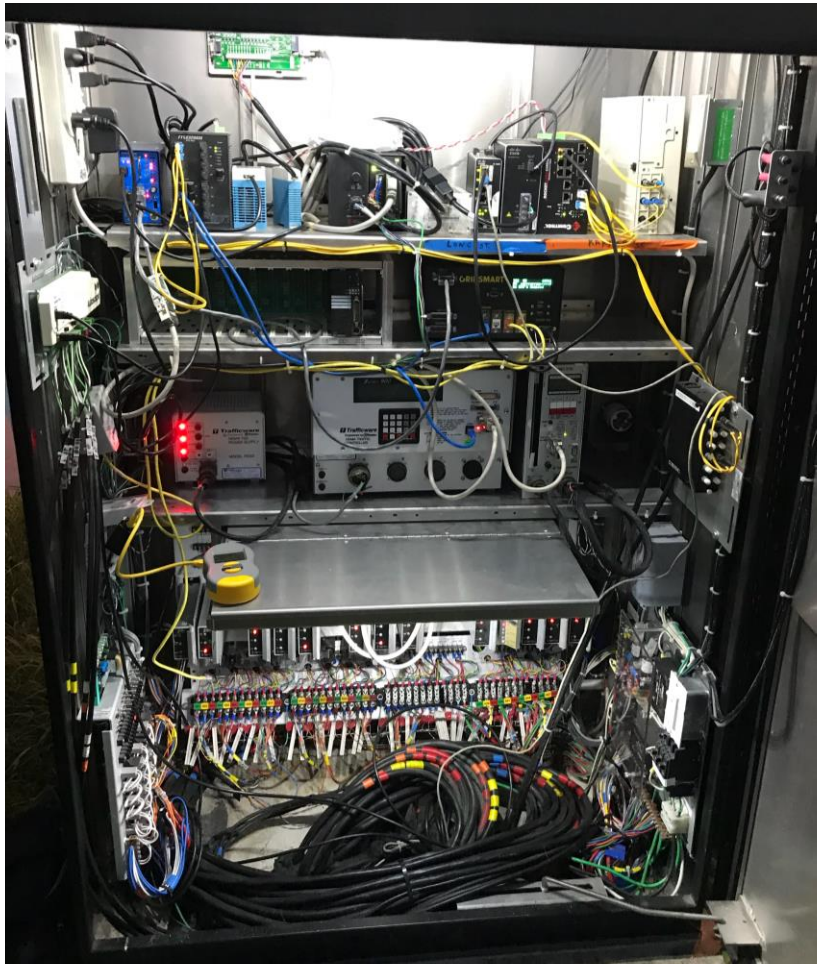
Challenges: Environmental. Expectations.

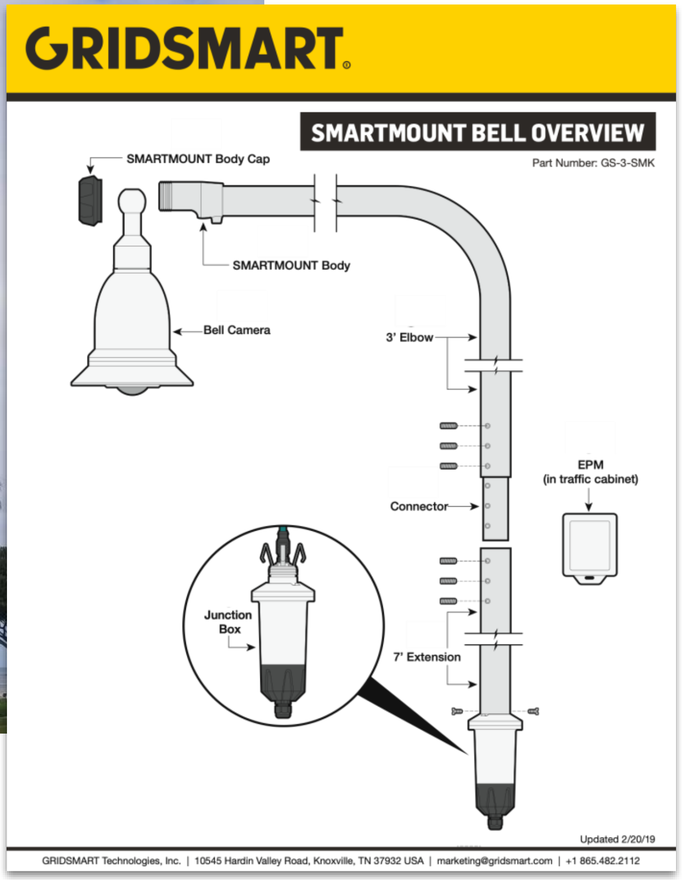
Need to operate at full functionality at 165F (74C) for 15 hours. Limited air flow.

Often near the ocean. Often near construction.

The industry generally expects of 7-10 year life cycle for the physical products as a minimum.



Challenges: Installation, environmental



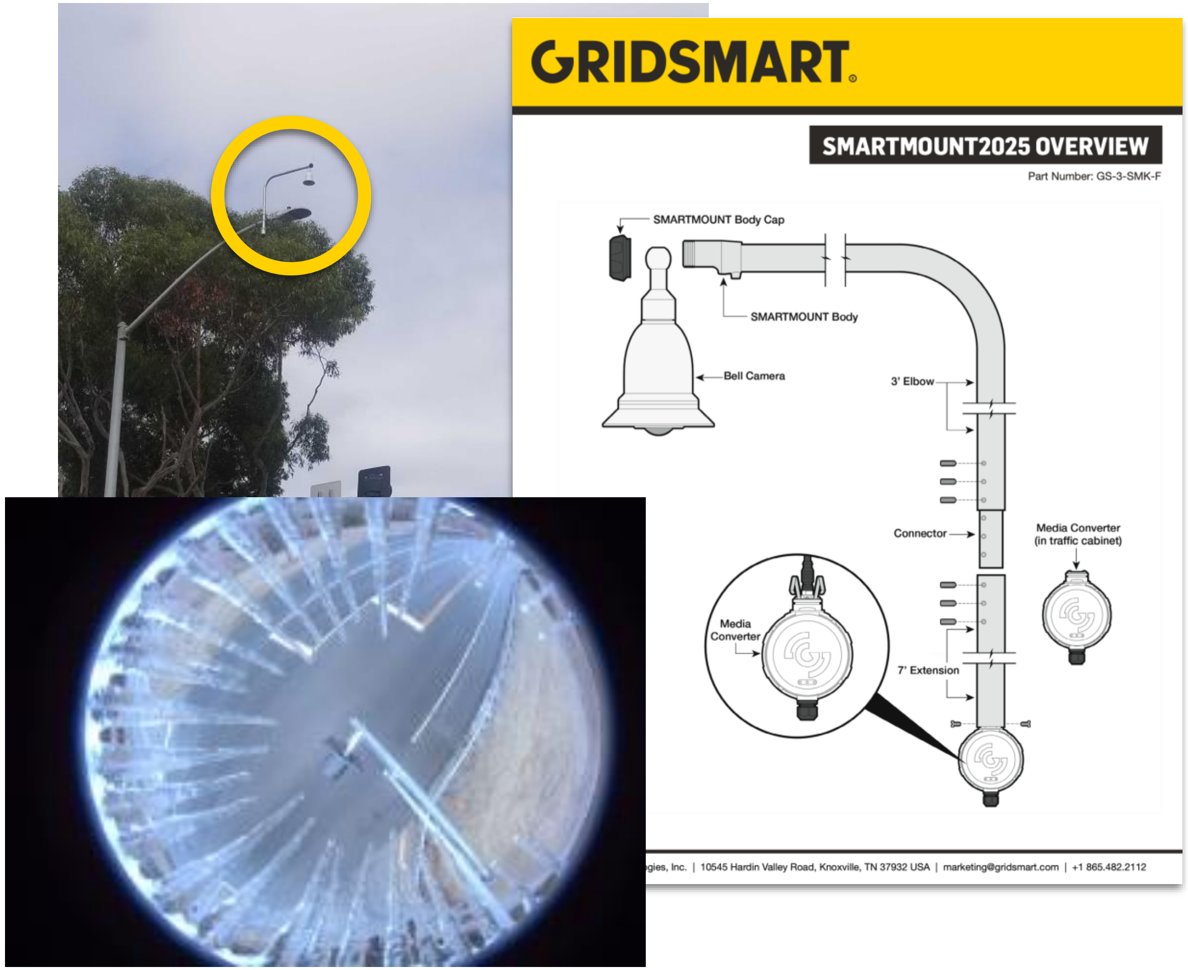
Do not ignore the physical realities of the installation, whether in your control or not.

Fisheye is better when mounted higher. But long poles are (very) expensive to ship.

Camera is susceptible to lightning strikes. Grounding and accessible surge protection are important.

A simplified installation, means a better installation and better performance.

Challenges: Installation, environmental



Ethernet cables to camera are often run alongside high-power cables. (Not a good thing.)

Ethernet cables can only go so far without need repeaters.

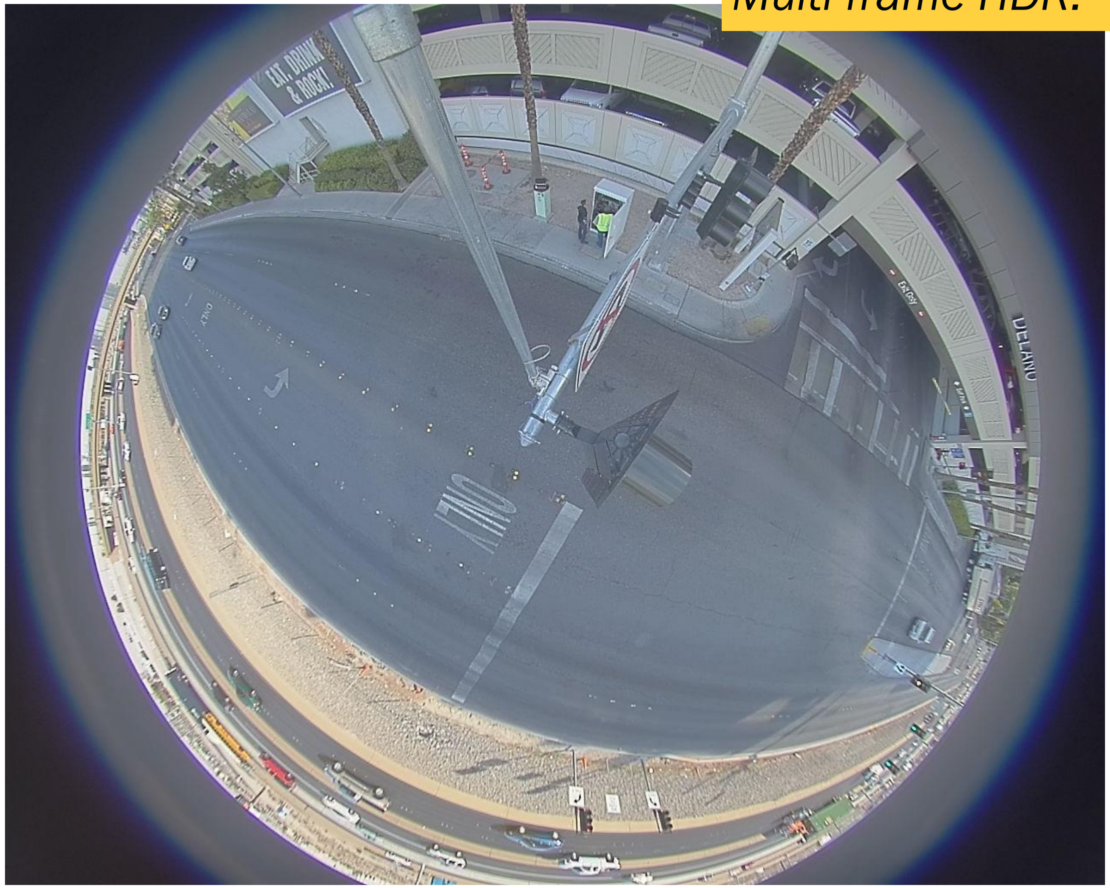
LED luminaires emit strong, noisy EM fields.

Cameras need ~50W power. (Why?)

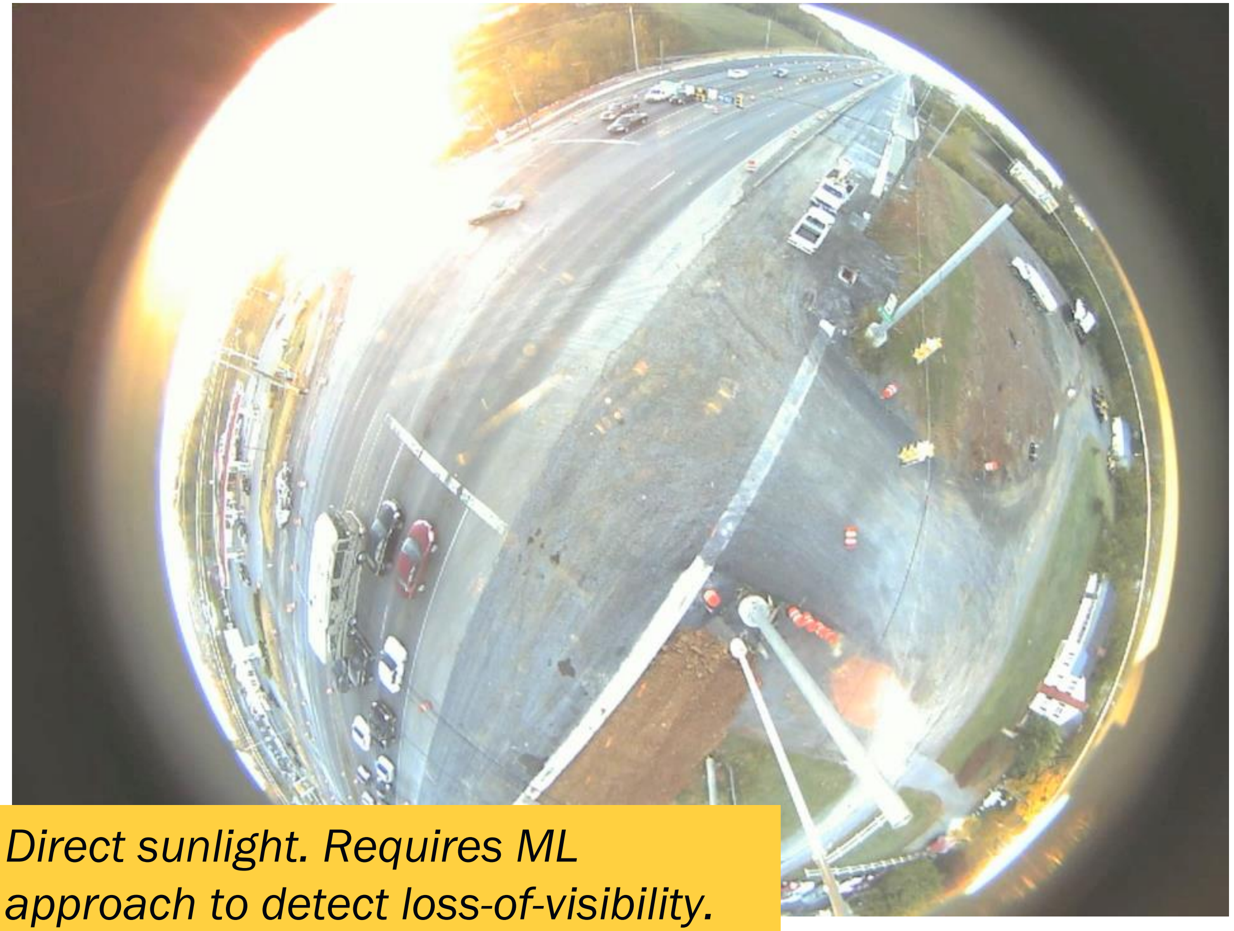
Challenges: Lighting

Single exposure.

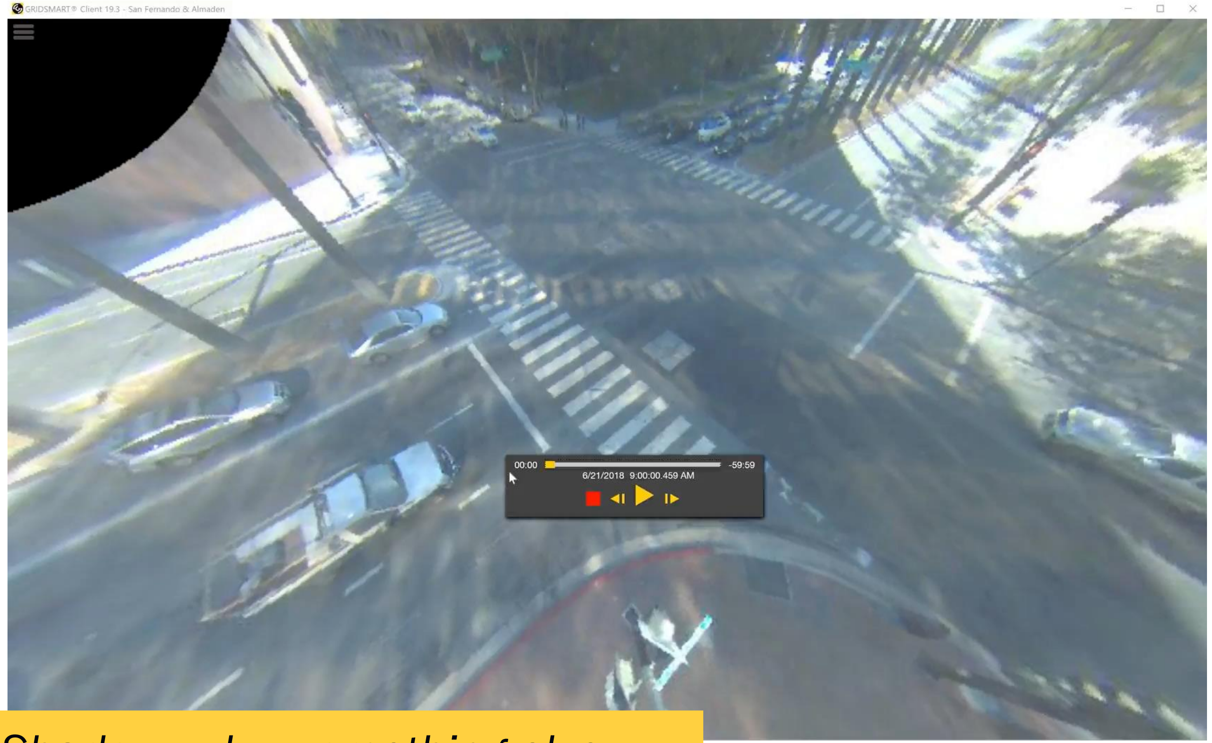
Multi-frame HDR.



Challenges: Lighting



Direct sunlight. Requires ML approach to detect loss-of-visibility.

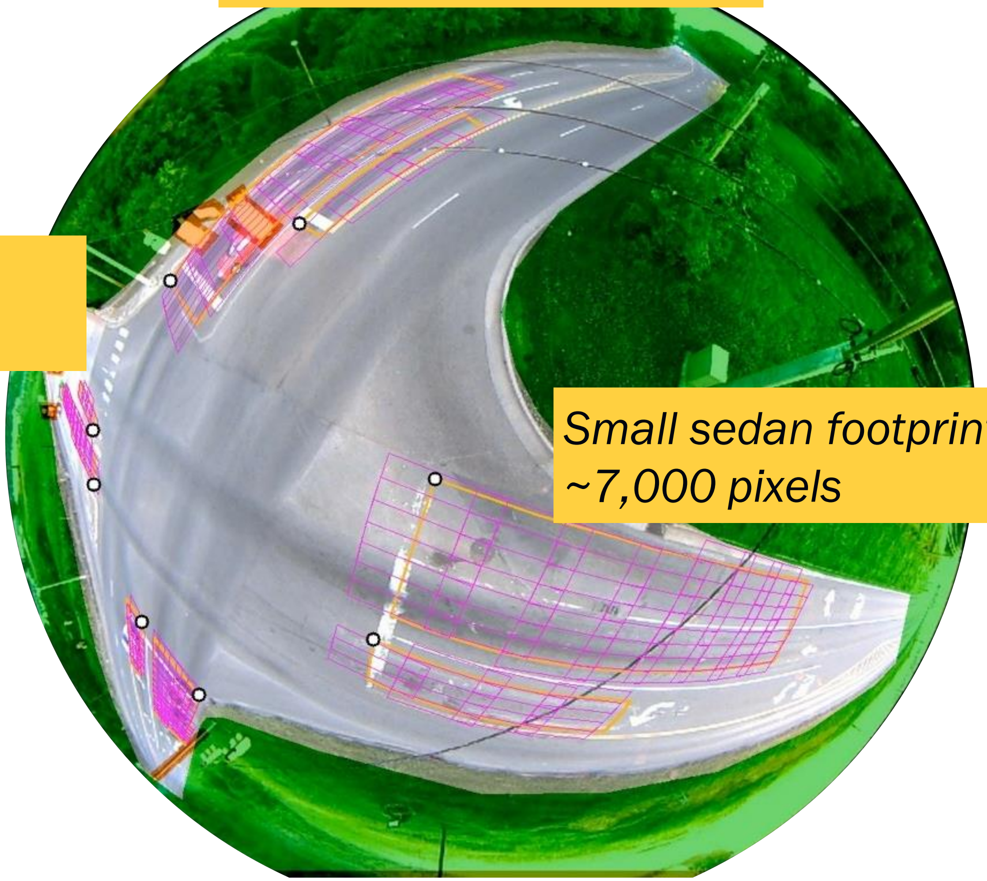


Shadows plus something else…

Challenges: Resolution (optics & pixels)

Optics: No Free Lunch

Small sedan footprint: ~40 pixels



Small sedan footprint: ~7,000 pixels

Closing Thoughts

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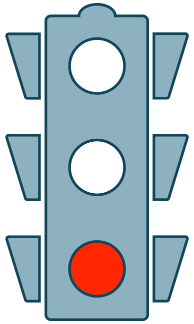
Closing Thoughts

Control as many aspects of your product as you can. Account for the things you cannot control. Make it easier to get right. Then make it easier again to get right.

How you do anything is how you do everything.

I believe in tracking all objects, not just those that you classify first. (That might change in near future.)



How did this all get started? Founders were sitting at a red light with no cars coming the other way.

Why in Knoxville, Tennessee? Fisheye imaging in the era of the internet boom (look up IPIX on Wikipedia).