

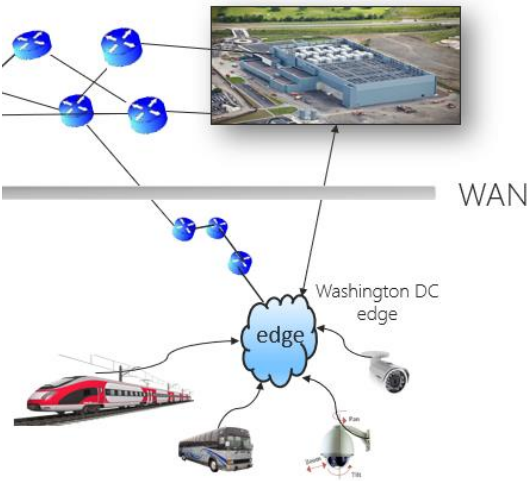
# live video analytics

extracting actionable insights from cameras in the wild

Victor Bahl  
Technical Fellow  
Microsoft Research

### 3. where are we going?

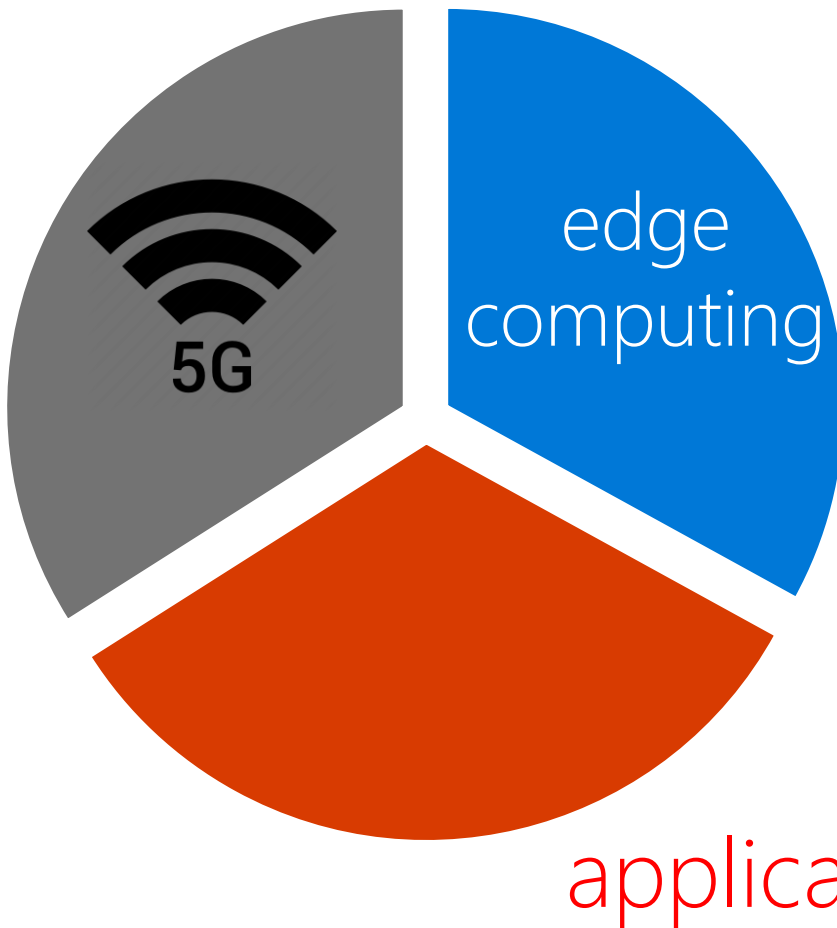
Azure US-East



**Computer**



# talk agenda



MICROSOFT CONFIDENTIAL

### 1. how did we get here?



### 2. what are we doing?

Project xCloud



8K x 120 Hz x 10 bit streaming

> 440 Mbps file downloads

live video analytics & derivatives

augmented reality

# smile, you are a star



THE WALL STREET JOURNAL.

China's 100 Million Surveillance Cameras

**theguardian**

You're being watched: there's one CCTV camera for every 32 people in UK



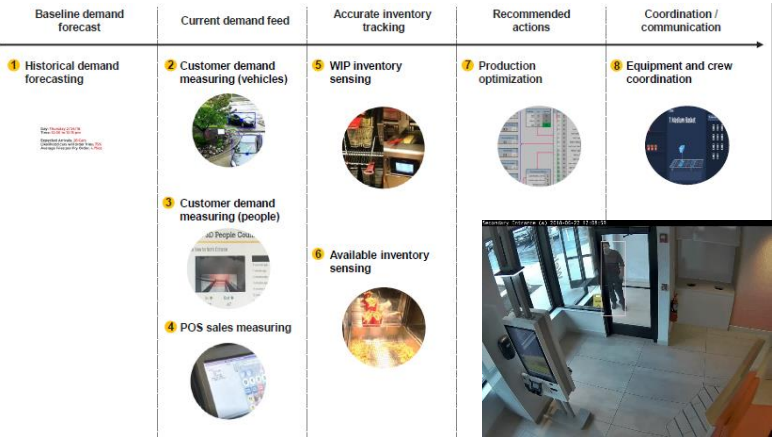
NYPD expands surveillance net to fight crime as well as terrorism

**a camera for every 8 people in the US & for every 29 people worldwide!**

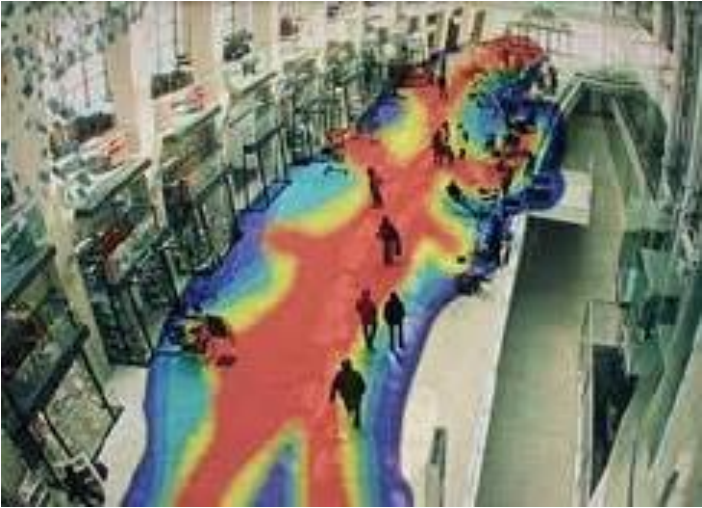
with cloud computing, it's the golden era for ML, computer vision, & AI

potential to impact science, society & business

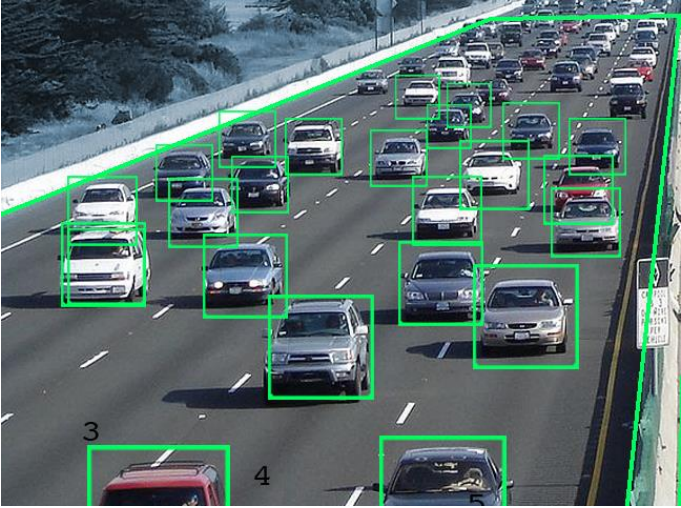
# scenarios



connected restaurants  
(e.g. McDonalds, Starbucks)



retail stores  
(e.g. Marks & Spencer)



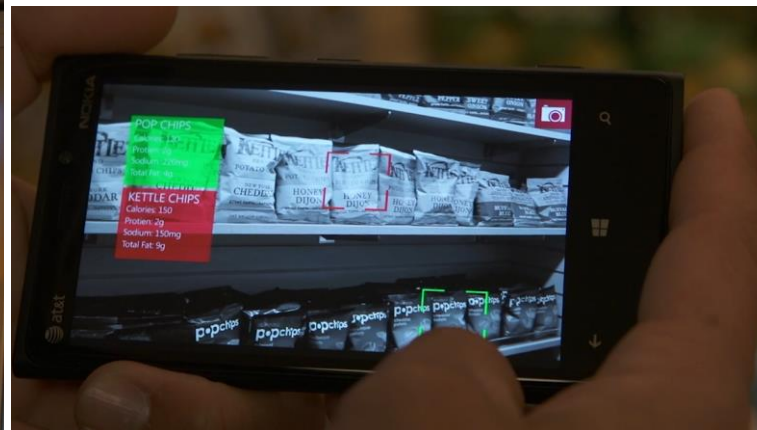
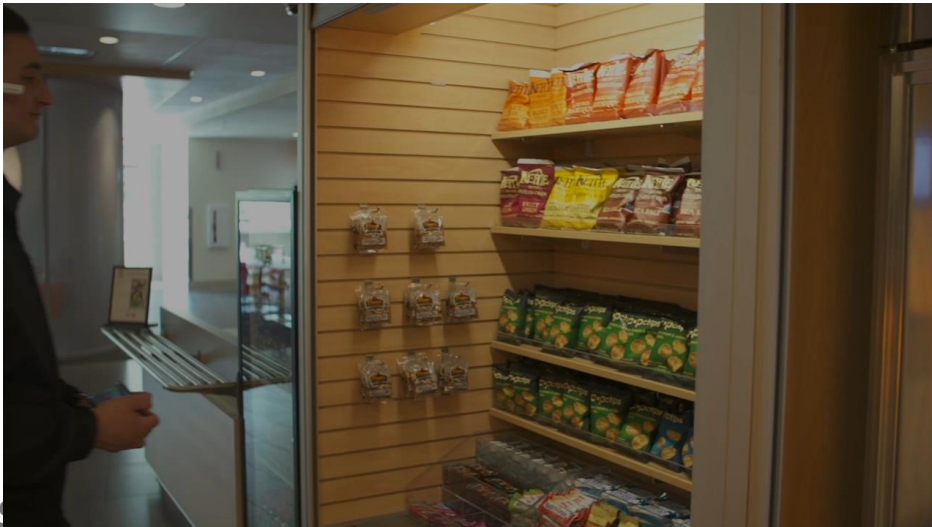
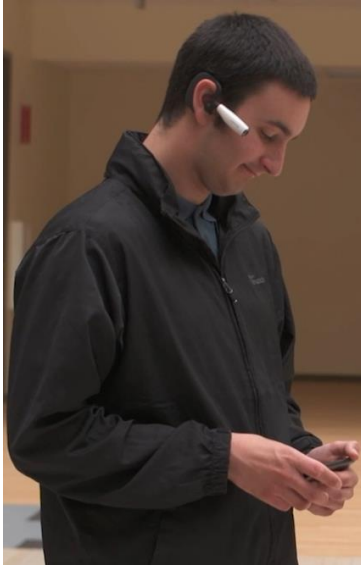
smart cities &  
urban mobility



# MSR's Glimpse project (2014)



<https://www.microsoft.com/en-us/research/video/glimpse/>



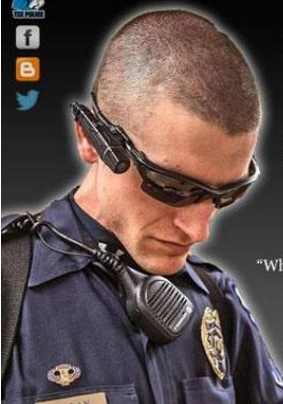
# body worn cameras, a real thing

**S**ince February of 2012, Rialto, California has required all police officers to wear a camera to monitor all interactions with the public.

**A**fter this practice was instituted, the number of complaints to the department dropped by **88%**. Further, the number of instances of the police using "force" on people dropped **40%**.

"When you put a camera on a police officer, they tend to behave a little better, follow the rules a little better..."  
- Chief William Farrar

FB/POLICETHEPOLICEACP

A police officer in a dark uniform is shown from the chest up, wearing a body camera on his forehead. He is looking down.

updated at 11:11 ET



## Metropolitan Police officers start wearing body cameras

The New York Times

### *New York Police Officers to Start Using Body Cameras in a Pilot Program*

By J. DAVID GOODMAN SEPT. 4, 2014



The Washington Post

### **D.C. police will wear body cameras as part of pilot program**

# in-vehicle video analytics for detecting open parking spaces in urban environment



Giulio



January 2015



video analytics - a systems problem

# six PhD thesis in systems so far ...

- **Kevin Hsieh**, *Low-Latency, Low-Cost Machine Learning Systems on Large-Scale, Highly-Distributed Data*, Carnegie Mellon University (September 2019)
- **Chien-Chun ("Michael") Hung**, *Resource scheduling in Geo-distributed Computing*, University of Southern California (December 2017)
- **Shubham Jain**, *Design of Inertial & Camera Sensing for Smart Intersections*, Rutgers University, (August 2017)
- **Grassi, Giulio**, *Connected cars: A computing resource for smart cities*, Université Pierre-et-Marie-Curie, Paris (October 2017)
- **Yuan (Tiffany) Chen**, *Interactive Object Recognition and Search over Mobile Video*, Massachusetts Institute of Technology (June 2017)
- **Robert LiKamwa**, *Vision Sensing Pipeline for Efficiency & Privacy*, Rice University (July 2016)

more coming ....



best paper award



highlights

lots of media coverage



Human and computer vision unite to help Microsoft engineers stop traffic deaths

BY LISA STIFFLER on June 1, 2017 at 6:00 am

NewScientist

Intelligent cameras can put an end to always-on surveillance

Many cities are packed with cameras pointlessly recording everything they see, but smart algorithms could allow them to keep only footage that matters



Microsoft looks to stop bike crashes before they happen, testing Minority Report-style predictive intelligence

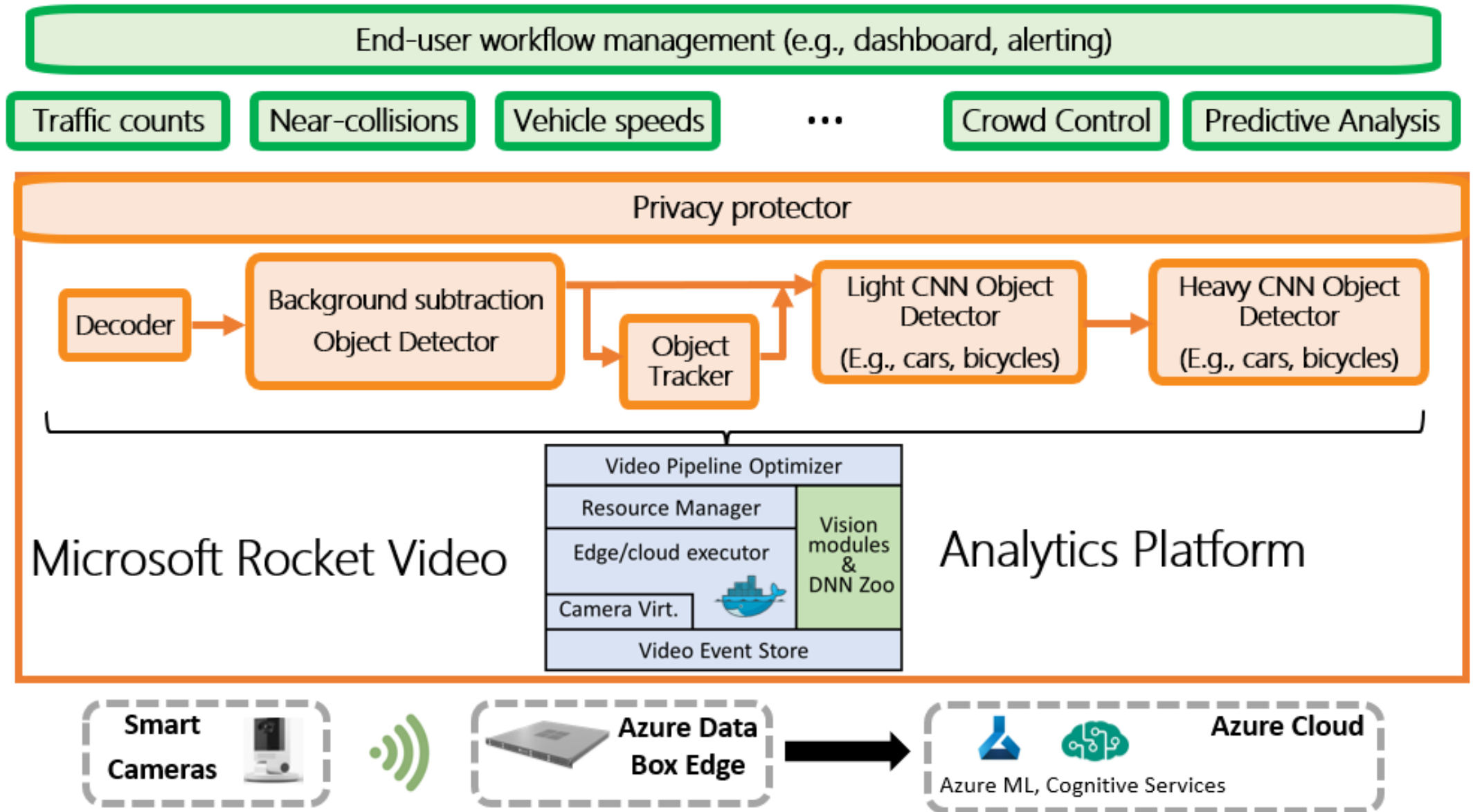
and many more ....

publications



systems people build systems...

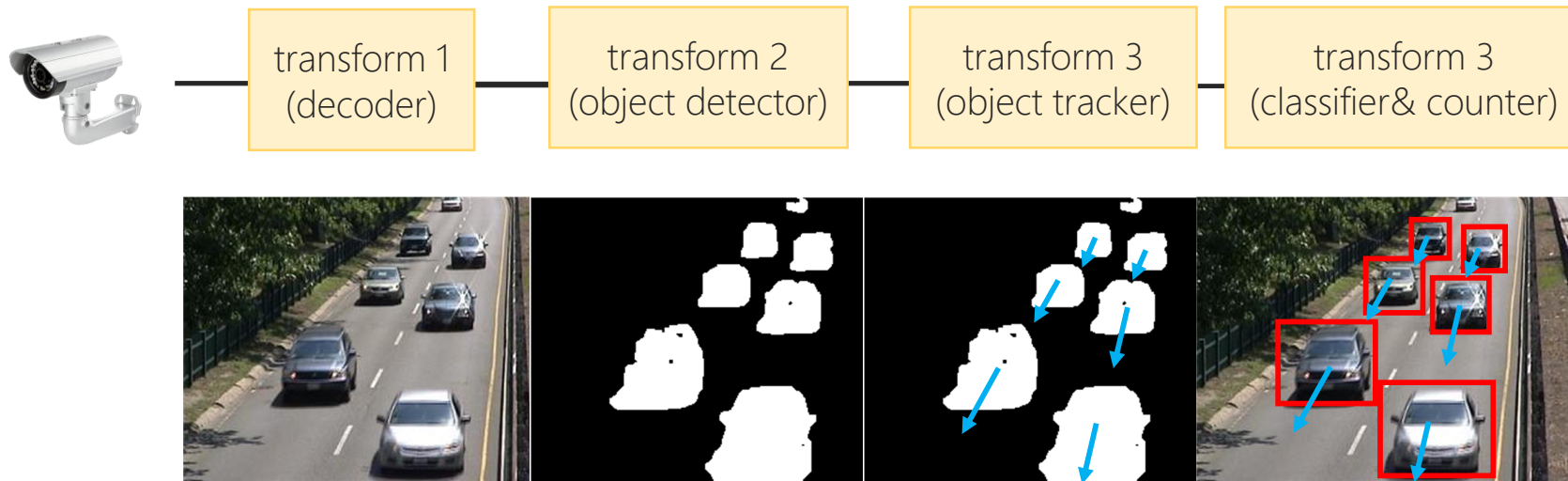
<http://aka.ms/rocket>



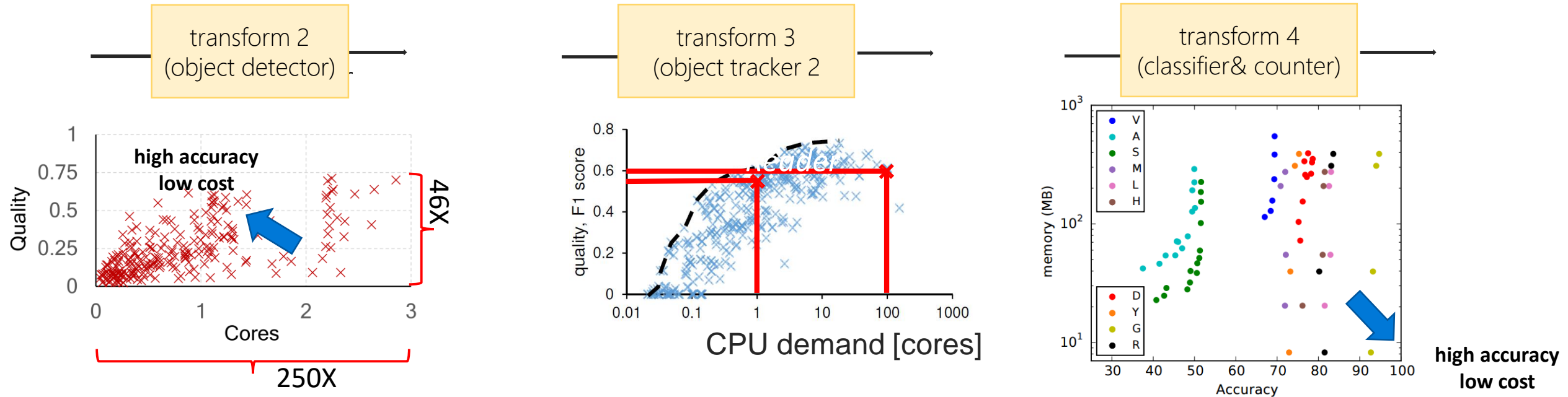
# video query: pipeline of transforms

vision algorithms ("*transforms*") chained together  
transforms implement specified interfaces

example: count the number of moving cars on a road segment



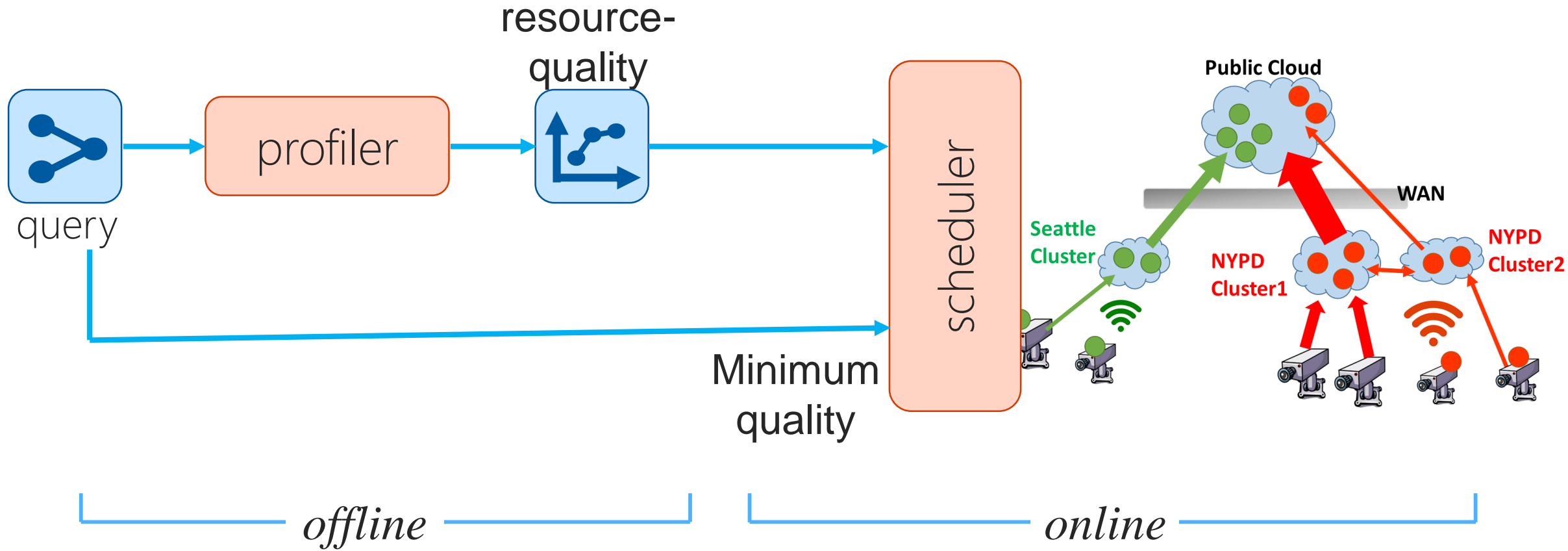
# each stage has a resource/quality trade off



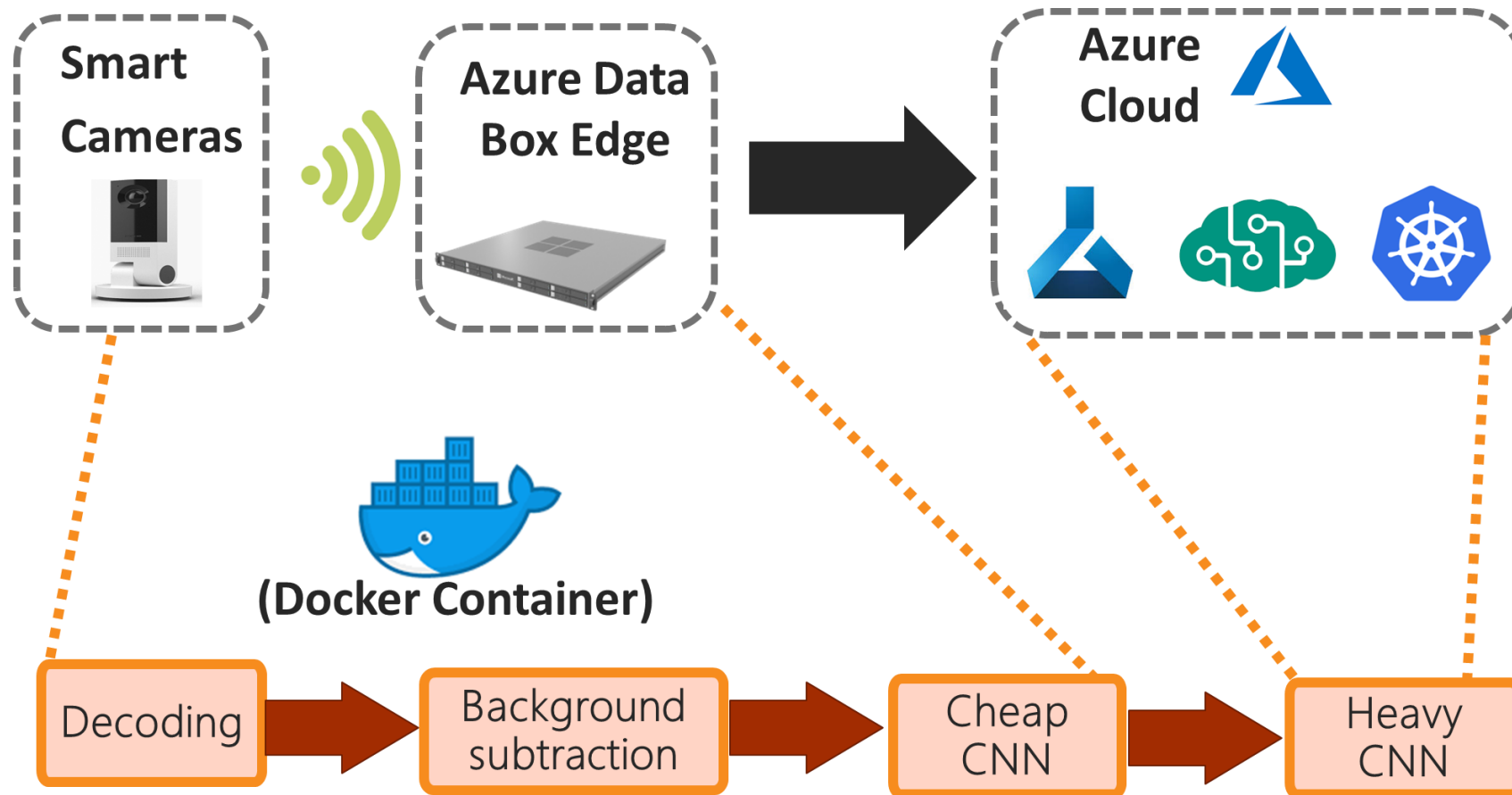
best car tracker<sup>[1]</sup> — 1 fps on an 8-core CPU  
DNN for object classification<sup>[2]</sup> — 30GFlops

no one plan is uniformly the best...  
best plan is dependent on the camera, lighting, track direction, object color, ...

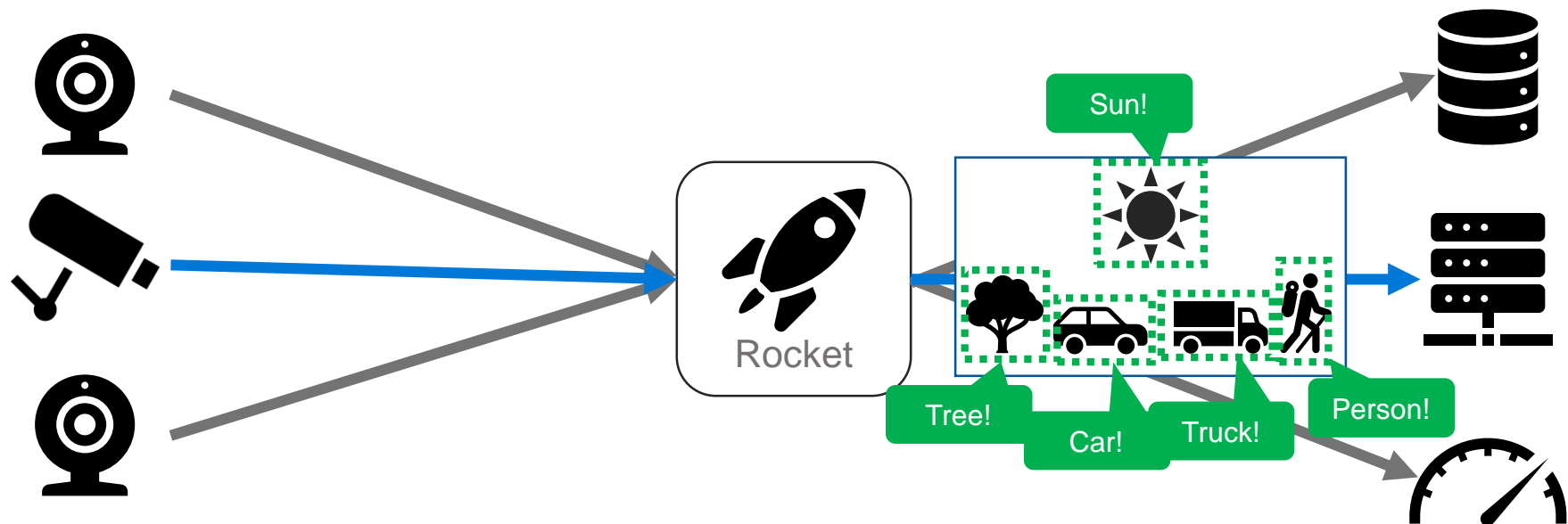
# how we handle this



# bandwidth sensitive transport

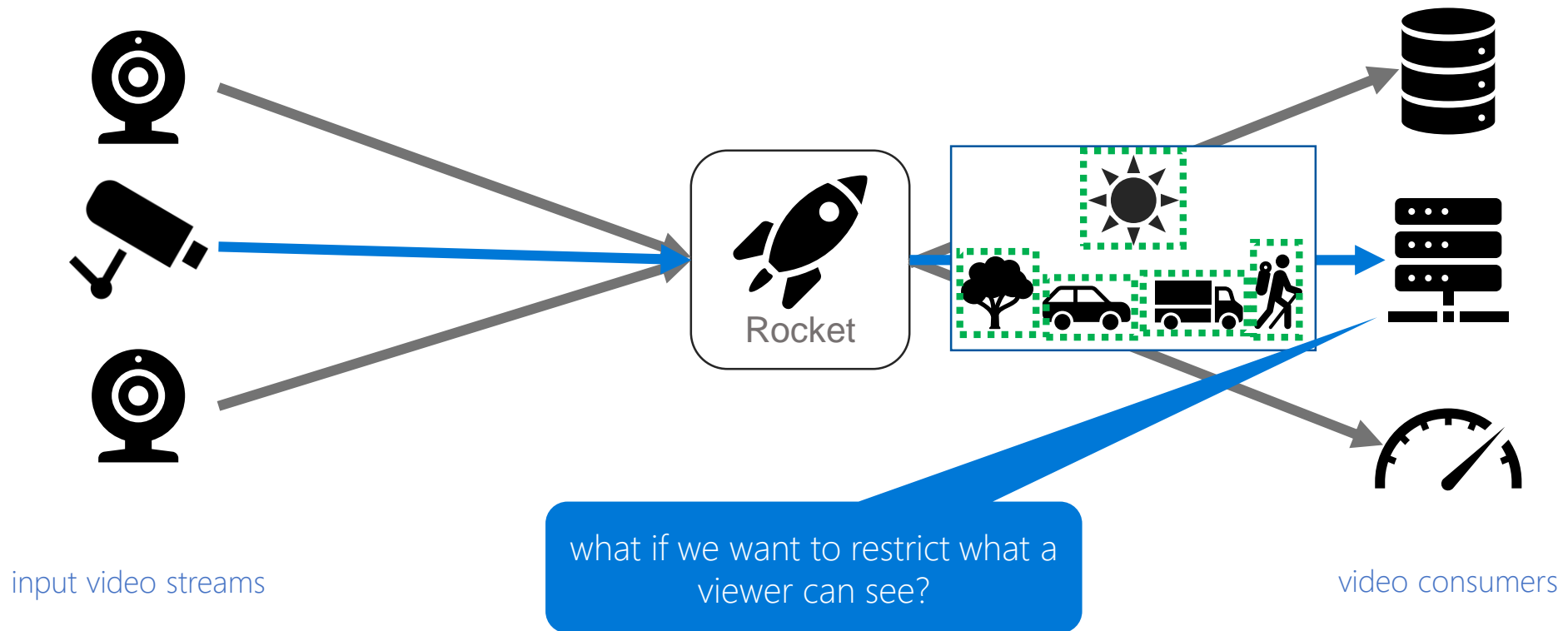


... it's video, we **care** about privacy

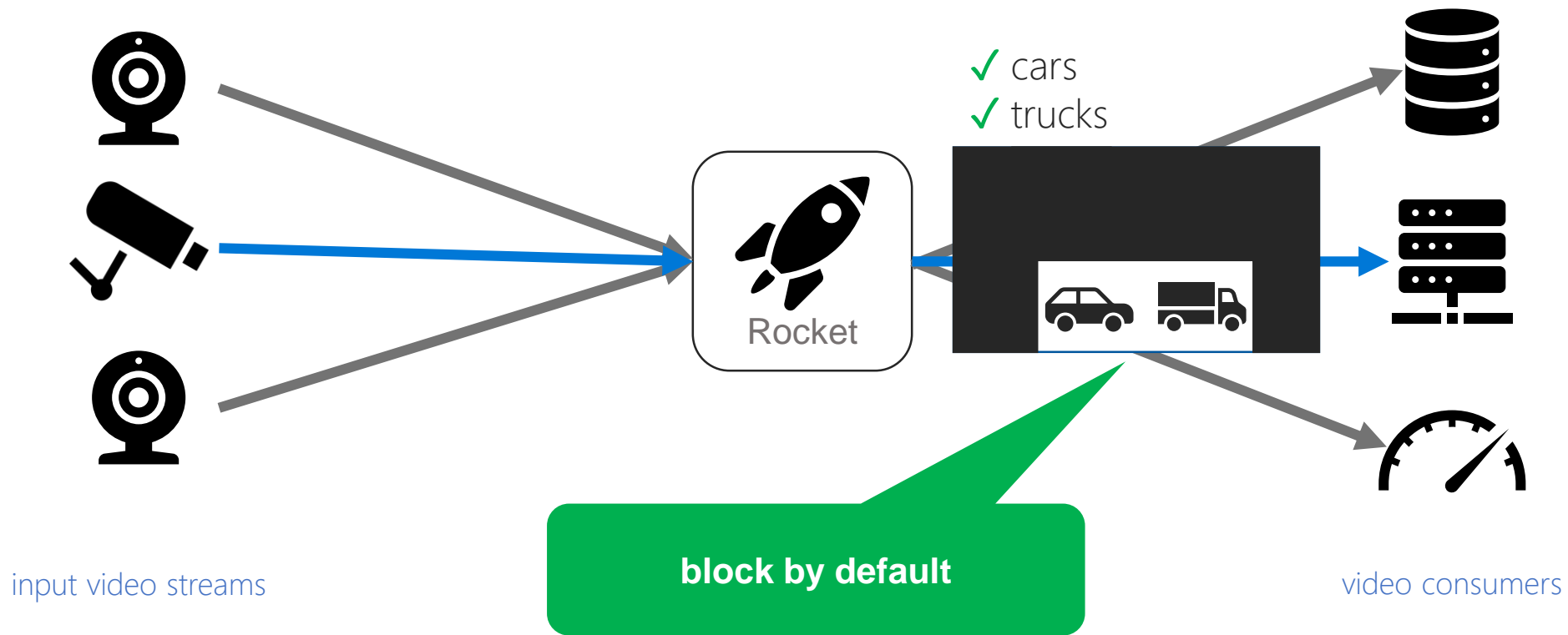


input video streams

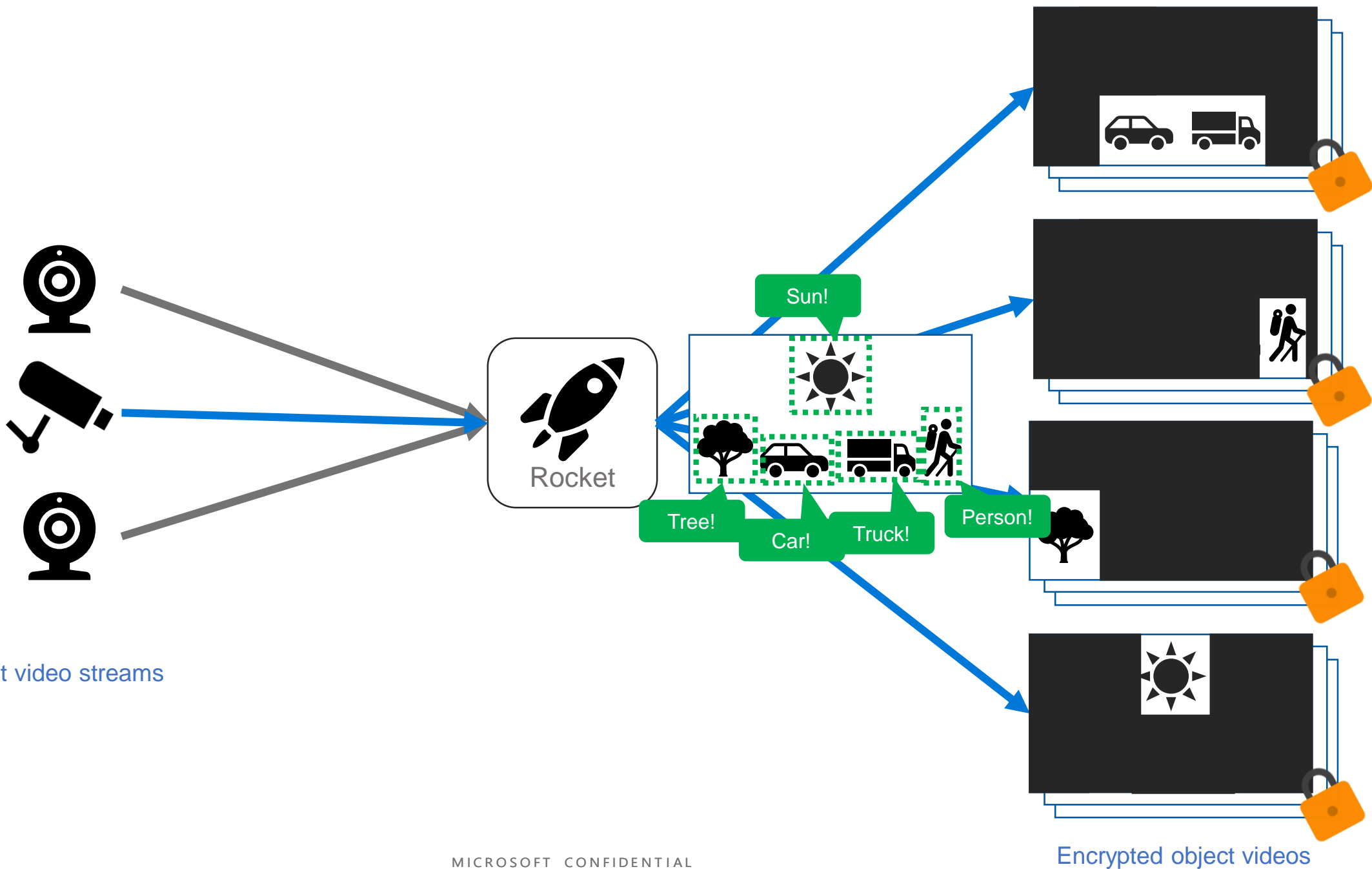
video consumers





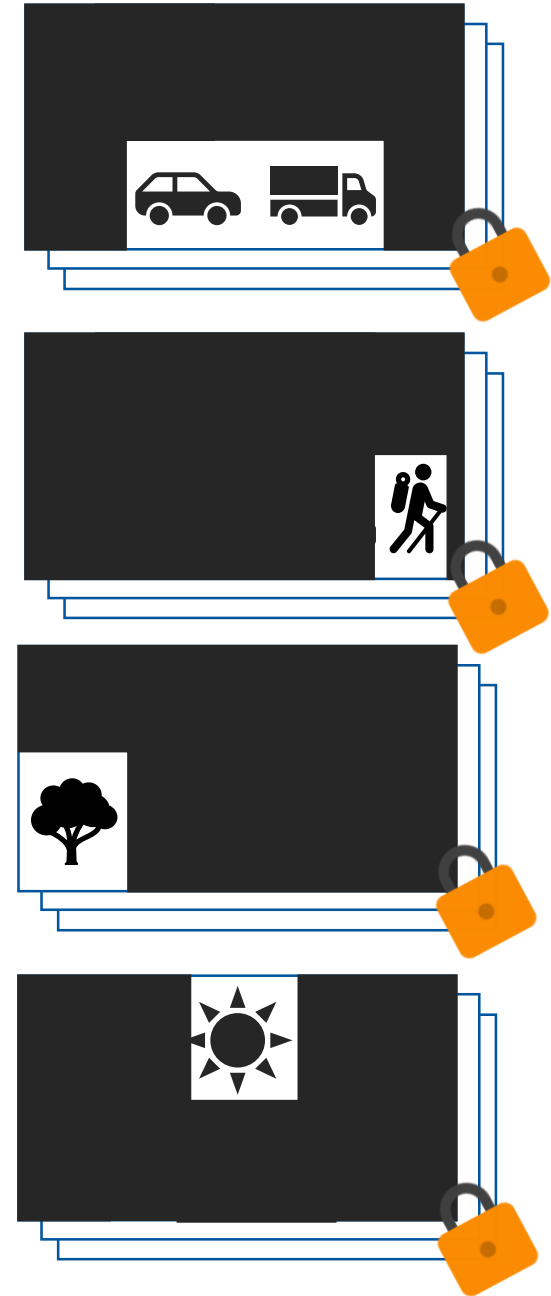






# object-specific streams

- ✓ easy to compress
  - redundancy across frames
- ✓ easy to protect
  - can encrypt video segments
  - distribute keys to authorized viewers
- ✓ easy to compose
  - create single view from multiple streams



# Rocket features & systems challenges

(built for pilots)

- ✓ line-based counting/alerting on live videos
- ✓ early filtering & selective DNN calls for efficient GPU/FPGA usage
- ✓ edge-cloud partitioning with cloud DNNs
- ✓ detect network unavailability, shift to “edge-only” mode
- ✓ resource-accuracy profiling to choose best configurations
- ✓ interactive after-the-fact querying on stored videos
- ✓ camera virtualization, multi-app support
- ✓ live redaction services
- ✓ easy scaling with smart pod /workload placement and orchestration

pilots & customer engagements

# some disturbing local news



## Hit-and-run driver nearly kills woman on bike in Bellevue

BY KOMO NEWS | WEDNESDAY, MARCH 23RD 2016

ADVERTISEMENT



## Car strikes, kills toddler in stroller in Bellevue

Originally published September 29, 2015 at 11:03 am | Updated September 30, 2015 at 10:27 am



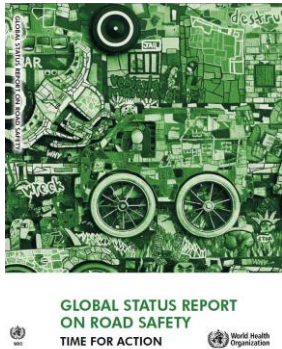
## 77-year-old pedestrian killed by teen driver in Bellevue

BY TIM HAECK, KIRO Radio Reporter | December 1, 2014 @ 10:17 am



local TV coverage

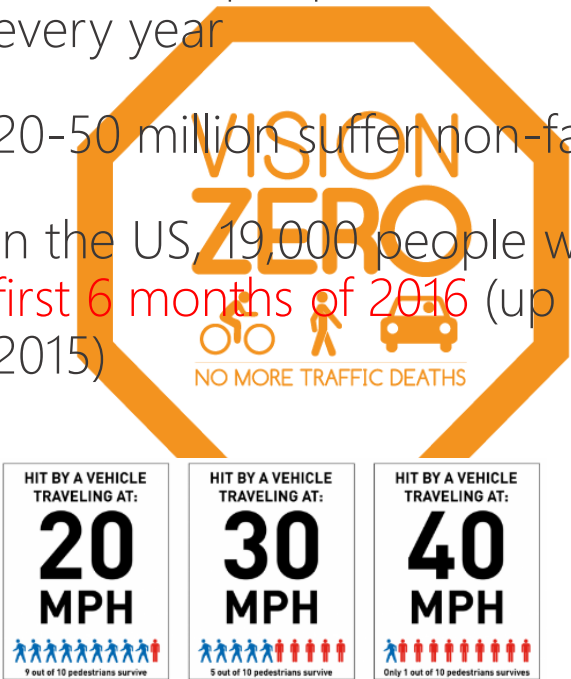
# traffic safety: a world-wide movement



- 1.2 million people die on the world's roads every year

- 20-50 million suffer non-fatal injuries

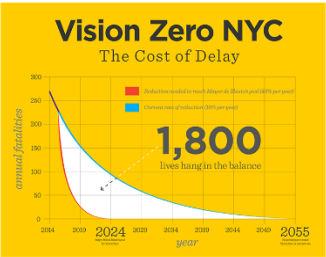
- in the US, 19,000 people were killed in the first 6 months of 2016 (up 9% compared to 2015)



**Vision Zero** is a multi-national road traffic safety project that aims to achieve a highway system with no fatalities or serious injuries in road traffic. It started in Sweden and was approved by their parliament in October 1997.

RANK	LEADING CAUSE	%
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Lower respiratory infections	7.0
4	Chronic obstructive pulmonary disease	5.1
5	Diarrhoeal diseases	3.6
6	HIV/AIDS	3.5
7	Tuberculosis	2.5
8	Trachea, bronchus, lung cancers	2.3
9	Road traffic injuries	2.2
10	Prematurity and low birth weight	2.0
11	Neonatal infections and other	1.9
12	Diabetes mellitus	1.9
13	Malaria	1.7
14	Hypertensive heart disease	1.7
15	Birth asphyxia and birth trauma	1.5
16	Self-inflicted injuries	1.4
17	Stomach cancer	1.4
18	Cirrhosis of the liver	1.3
19	Nephritis and nephrosis	1.3
20	Colon and rectum cancers	1.1

cities all over North America are embracing it



# Bellevue & Microsoft Research collaborate on Vision Zero

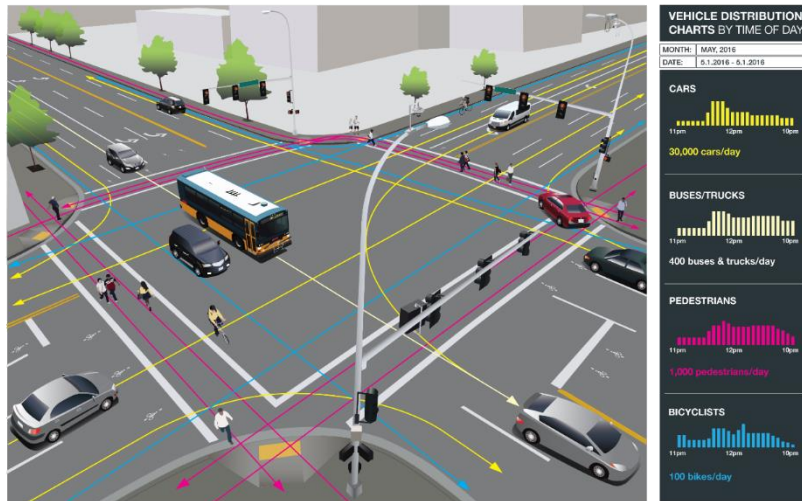
use widely deployed traffic cameras

- Car/bike/ped counts, near-collisions, anomalies



Making Bellevue a great place  
to **walk** and **bike**.

next-generation traffic control



Amy Carlson,  
Vice President & Area Office Manager, CH2M Hill



# picked up by local media

**GeekWire**

## Microsoft looks to stop bike crashes before they happen, testing Minority Report-style predictive intelligence

BY LISA STIFFLER on October 14, 2015 at 1:00 pm

declined interview but...



# why focus was on intersections?

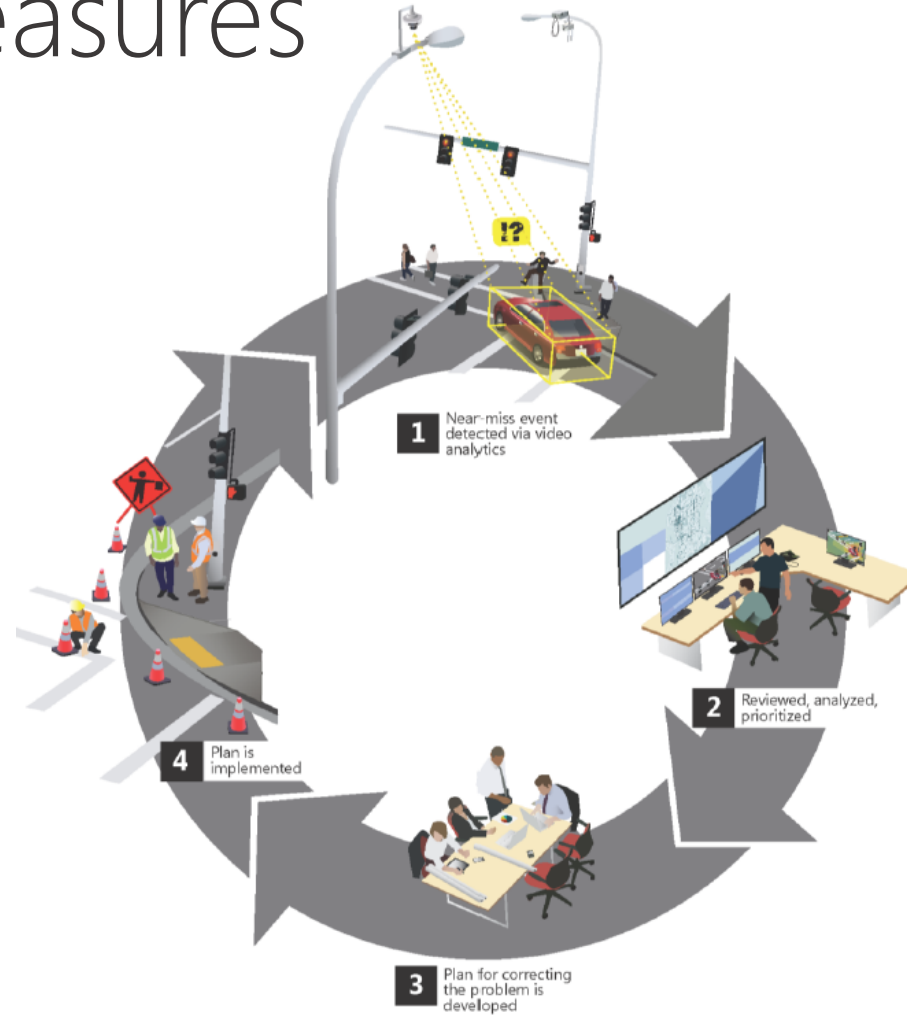
~20% fatal crashes happen at intersections  
~50% of all crashes happen at intersections

and if this is not enough to motivate you, consider the business potential ...

United States has ~330,000 intersections with traffic signals

RANK	LEADING CAUSE	%
1	Ischaemic heart disease	12.2
2	Cerebrovascular disease	9.7
3	Lower respiratory infections	7.0
4	Chronic obstructive pulmonary disease	5.1
5	Diarrhoeal diseases	3.6
6	HIV/AIDS	3.5
7	Tuberculosis	2.5
8	Trachea, bronchus, lung cancers	2.3
9	Road traffic injuries	2.2
10	Prematurity and low birth weight	2.0
11	Neonatal infections and other	1.9
12	Diabetes mellitus	1.9
13	Malaria	1.7
14	Hypertensive heart disease	1.7
15	Birth asphyxia and birth trauma	1.5
16	Self-inflicted injuries	1.4
17	Stomach cancer	1.4
18	Cirrhosis of the liver	1.3
19	Nephritis and nephrosis	1.3
20	Colon and rectum cancers	1.1

# city planners need data & analytics to perform corrective measures

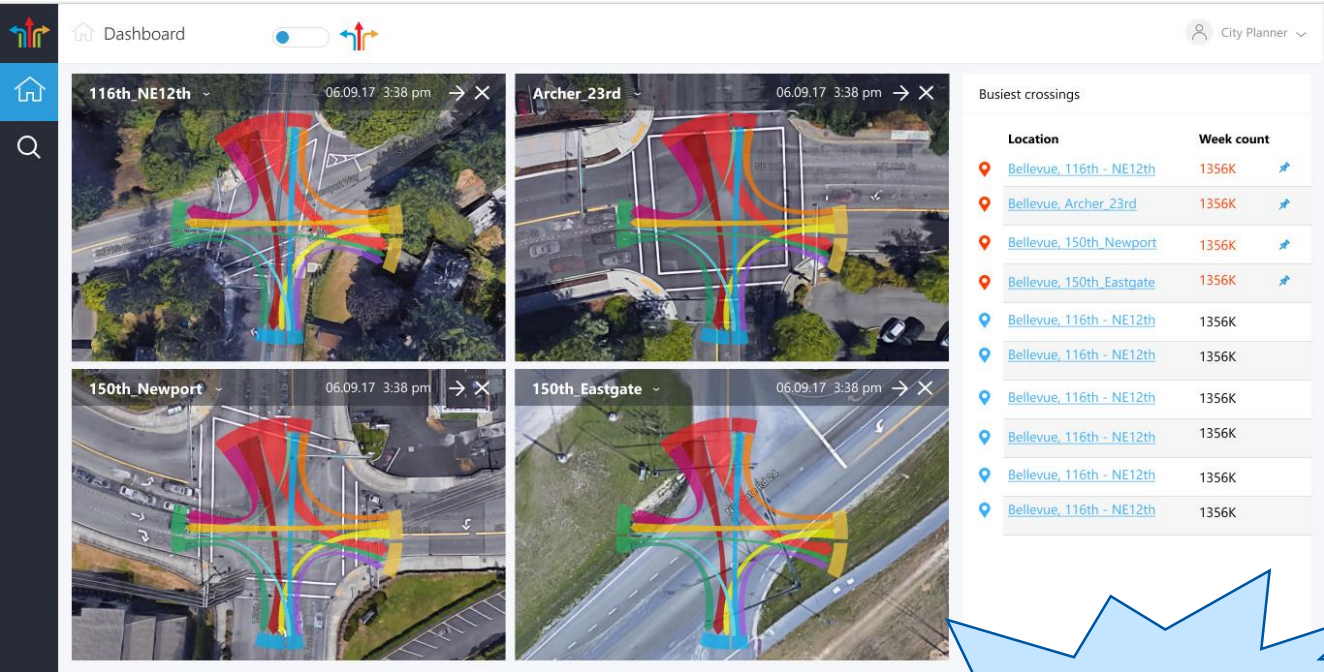


2005 - 2010 60 collisions recorded by the Bellevue Police Department

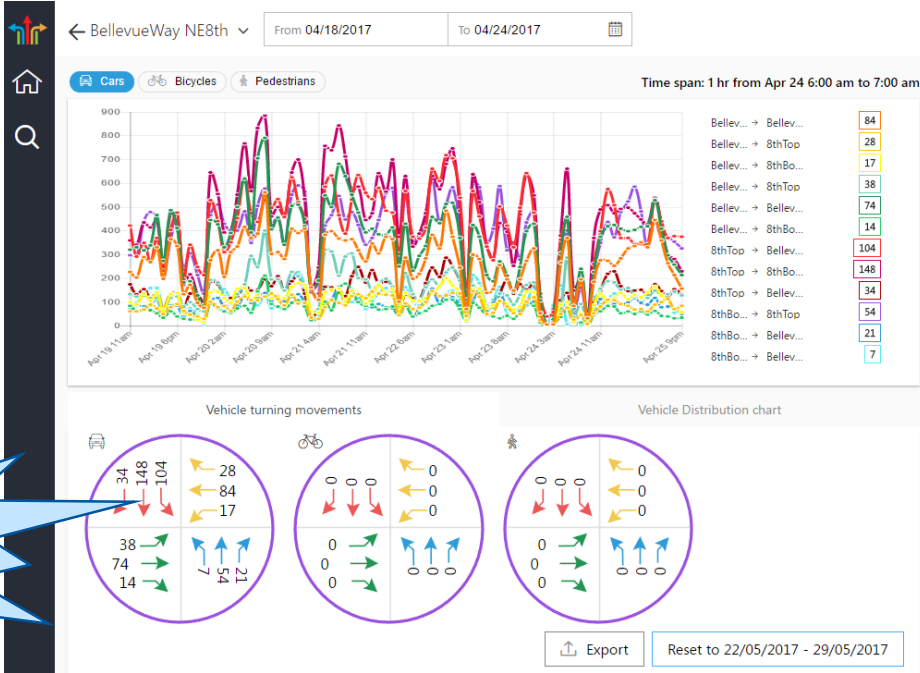


In 2013, WSDOT built a new roundabout at the intersection

# live at Bellevue's Traffic Management Center



24X7 on live traffic feeds



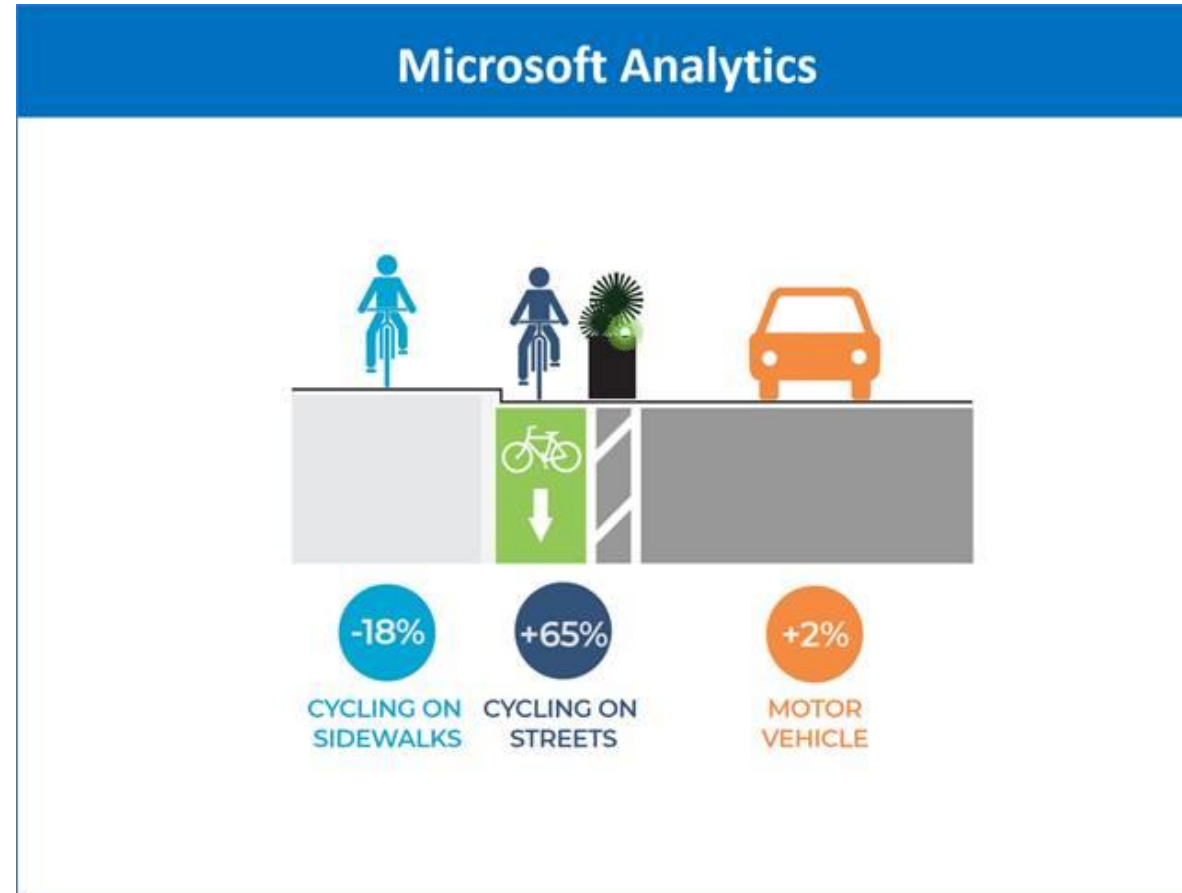
# Microsoft + Bellevue Vision Zero Collaboration 2017 - 2019





# 108<sup>th</sup> Avenue NE, Bellevue, Washington

## bike lane project



cycling on sidewalks has reduced, on-street bicycle usage has increased due to the bike lane,& the volume of motor vehicle traffic is unaffected.

PARTNERSHIPS

# Video Analytics Towards Vision Zero

By FRANZ LOEWENHERZ, VICTOR BAHL, PH.D., AND YINHAI WANG, PH.D.

For young people below the age of 35, motor vehicle crashes are the leading cause of death in the United States. In 2015, collisions resulted in 35,092 deaths and 2.4 million injuries. More than 1,100 children under the age of 15 were killed. The 7.2 percent increase in traffic fatalities from 2014 to 2015 represents the greatest percentage increase in nearly 50 years.<sup>1</sup> Yet despite the massive death toll, work to prevent traffic fatalities has been woefully lacking.

Many governmental agencies continue to rely on traditional traffic safety approaches. They intervene only after enough police crash reports are filed to trigger a High Crash Corridor designation. This reactive approach to preventing crash recurrence has well-documented limitations:

- At most locations, the number of crashes is very small and subject to chance variations;
- Not all crashes are reported and the level of reporting is uneven regarding the type of road users involved, the exact location, and the severity of injuries;
- Numerous "close calls" go undocumented; and
- Many years of crash data are typically required to develop an understanding of the situation.<sup>2</sup>

Given these trends, and the crash analysis tools presently employed, how will jurisdictions achieve what all of us want: zero fatalities and serious injuries on our roadways? That's the goal of Vision Zero,

what is one of the leading causes of death worldwide.<sup>3</sup> It calls on government agencies to be proactive, identify risks, and take steps to prevent injuries on our roadways. Vision Zero encourages us to imagine a future in which we do not need to wait for crashes to occur in order to prevent others from happening.<sup>4</sup>

**Solutions for a Safer World**

Although traffic collisions can happen anywhere, there are often early warning signals in the form of conflicts or near-collision events at specific locations. These are recurring instances where a car abruptly stops because a bicycle veered in front of it, a pedestrian steps into the path of a bicyclist, or one bicyclist or car passes by another or a static object at very close spacing. These surrogate warning indicators – observable non-crash traffic conflict events – provide insight into when, where, and why crashes are most likely to occur. Understanding the root causes for near-collision events could enable local governments to take proactive,

## public crowd-sourcing for labeled data

Menu
REPORTER
News Sports Life Business Opinion Letters to the Editor

### Volunteers needed to improve traffic safety using high-tech

By Adam Gable  
Updated: Jun 1, 2017 - 6:53 PM

### Bellevue premieres national program to reduce traffic deaths

GREATER GREATER WASHINGTON  
The Washington, DC region is great >>> and it can be greater.

GeekWire
TRENDING: Amazon poised to lease iconic new Seattle office tower, dramatically expanding footprint again

### Human and computer vision unite to help Microsoft engineers stop traffic deaths

BY LISA STIFFLER on June 1, 2017 at 6:00 am

TRANSPORTATION HOUSING PUBLIC POLICY DC MARYLAND VIRGINIA

### We can use data to achieve Vision Zero by spotting dangerous places before crashes happen

ROADS By Daniel Warwick (Advocacy Committee) June 19, 2017 9

### Vision Zero video tool analyzes intersections for dangerous traffic conflicts

**Microsoft**

**IEEE**

MICROSOFT CONFIDENTIAL

# global partners



# press release by DC DOT



**FOR IMMEDIATE RELEASE:**  
August 30, 2017

**MEDIA CONTACTS:**  
LaToya Foster (EOM) – (202) 727-5011; [latoya.foster@dc.gov](mailto:latoya.foster@dc.gov)  
Terry Owens (DDOT) – (202) 763-8635; [terry.owens@dc.gov](mailto:terry.owens@dc.gov)

## Mayor Bowser to Mobilize Residents in Vision Zero Crowdsourcing Partnership *Analysis of Traffic Camera Footage to Support Vision Zero*

(WASHINGTON, DC) – Today, as part of Washington, DC’s Vision Zero initiative, Mayor Bowser announced the Video Analytics Towards Vision Zero project, a cutting-edge partnership between the District and Microsoft that will use video footage and crowdsourcing to prevent traffic accidents. The project will tap artificial intelligence and new technologies to analyze traffic camera video footage and use near-miss collisions to predict where crashes are likely to occur in the future.

*“Using video analytics to achieve Vision Zero is one more way we are building a smarter, safer, stronger DC,” said Mayor Bowser. “Residents know traffic issues in their neighborhoods better than anyone, and now we will be able to leverage their knowledge with our existing camera infrastructure in order to prevent crashes and injuries before they occur.”*

The District has over 130 closed circuit television cameras around the city that are used to observe traffic conditions at intersections, and as part of this project, Microsoft has developed a crowdsourcing platform that will allow members of the public to review video footage and use tracking tools to identify movements and objects. People will be able to identify objects such as pedestrians, bicyclists, drivers, and motor-vehicles. The feedback will be used as part of a process where people will teach computers how to tell the difference between different movements and modes of transportation. Ultimately, instead of a person watching hours of video, computer algorithms will be able to analyze millions of hours of footage.

“The video analytics project will help us identify potential hazards at intersections throughout the District. Traditionally, we have used crash data for this purpose, but this new approach will help DDOT detect problems before crashes happen and before anyone is injured,” explained DDOT Interim Director Jeff Marootian.

“Computer vision algorithms applied to video feeds from traffic cameras have a huge potential of improving traffic flow and reducing traffic crashes and fatalities. We are working diligently on this because we truly believe the societal impact will be significant,” said Microsoft Research Distinguished Scientist Victor Bahl.

Residents can participate in the crowdsourcing platform by visiting the program website: <http://www.ite.org/visionzero/videoanalytics/>.

Vision Zero is the District’s plan to eliminate fatalities and serious injuries to people walking, biking, and driving within Washington, DC by the year 2024. To learn more about Washington, DC’s Vision Zero initiative, visit [ddot.dc.gov/page/vision-zero-initiative](http://ddot.dc.gov/page/vision-zero-initiative).

###

**Social Media:**  
Mayor Bowser Twitter: [@MayorBowser](https://twitter.com/MayorBowser)  
Mayor Bowser Instagram: [@Mayor\\_Bowser](https://www.instagram.com/Mayor_Bowser)  
Mayor Bowser Facebook: [facebook.com/MayorMurielBowser](https://facebook.com/MayorMurielBowser)  
Mayor Bowser Website: [mayor.dc.gov](http://mayor.dc.gov)

# mayor's challenge award to Bellevue

## Safer Cities, Safer People Award



U.S. Department of Transportation

MAYORS' CHALLENGE

GATHER DATA



Winner!  
Bellevue, Washington

Bellevue, WA, pursued a range of data collection activities during the Mayors' Challenge to identify barriers to bicycling and walking, prioritize improvements, and guide investments. In February 2015, the Bellevue City Council introduced the Pedestrian and Bicycle Implementation Initiative (PBII) to improve safety for people of all ages and abilities who walk and bike in Bellevue. Using data collected from online sources, key-pad polling at public meetings, automated bicycle and pedestrian counters, and traffic camera videos, the PBII team identified barriers to walking and bicycling and developed a \$6.8M Bicycle Rapid Implementation Program (BRIP) budget proposal to guide citywide investments through 2019. The BRIP aims to expand the city's bicycle network from 42 miles to more than 70 miles of conventional bike lanes, separated lanes or off-street paths, and to complete four continuous, cross-city bicycle corridors.

**Demonstrated Successes**

**Innovative Data Collection Techniques: Gather Real-Time and Long-Term Data with Public Input**

Throughout the PBII process, Bellevue has

- emphasized understanding long-term trends and gathering feedback from people who walk and bike. Bellevue's PBII team:
- Conducted a longitudinal assessment from 2006–2015 of non-motorized collisions using the USDOT's Pedestrian and Bicycle Crash Analysis Tool (PBCAT) system;
- Gathered input using key-pad polling and comment cards at 20 public meetings and an open house that attracted 140 attendees; and
- Used online surveys to solicit public input at two stages in the BRIP development process:
  - Over 700 people placed more than 1,600 points in the first online map to identify locations that they felt were unsafe for walking and bicycling;
  - Over 120 people submitted more than 400 comments on conceptual designs for 52 proposed projects to make the pedestrian and bicycle systems safer.



Pedestrian and Bicycle project manager Franz Loewenherz (foreground) and Councilmember Lynne Robinson (center) lead a policy ride with local bicycle advocates in Downtown Bellevue.

MAYORS' CHALLENGE: CHALLENGE ACTIVITY 3 (GATHER DATA)

1



Video Analytics analyzes traffic camera video footage and uses near-miss collisions to predict where future crashes are likely to occur. Traffic engineers could then take corrective action to prevent them. File photo

## Bellevue video analytics project receives safety award

Fri Aug 4th, 2017 3:44pm • BUSINESS



# Achievements Award



## U.S. Department of Transportation

# consider the following

United States has ~330,000 intersections with traffic signals

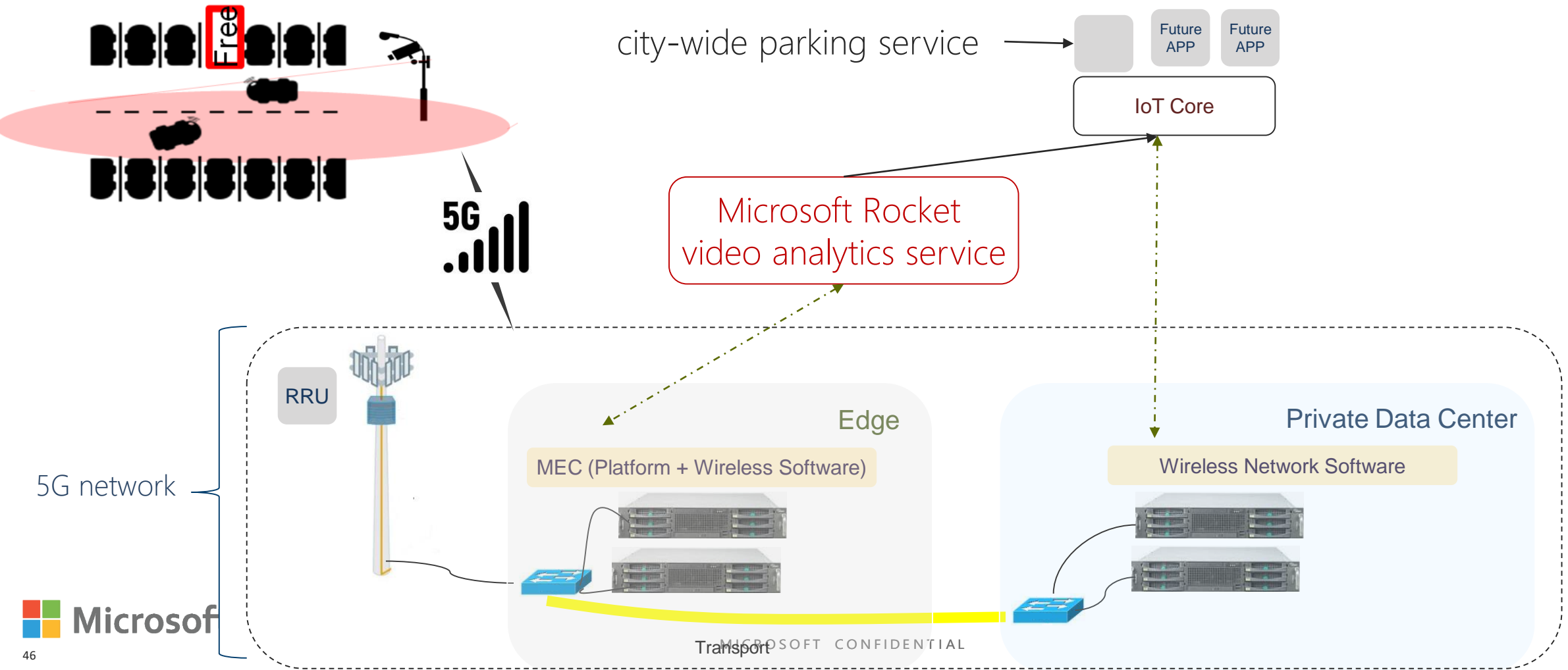
## revenue potential

- Brisk Synergies charges \$5,000 for traffic counts *per intersection for one day of recorded video*  
City of Bellevue has 200 cameras; counts done once a quarter is \$4M/year  
(Bellevue is the 177<sup>th</sup> most populated city in the USA)
- London's million cameras online on Azure → **\$65 million/month**  
(packing 10 streams per GPU-VM)

pilot 2 : parking in congested cities  
pilot 3 : self driving cars

# Company A -Microsoft (5G era) pilot

finding parking increases congestion (driving in circles), CO & CO2 emission, and stress



Mar/08/2019 09:09:48AM

Cars: 15/56

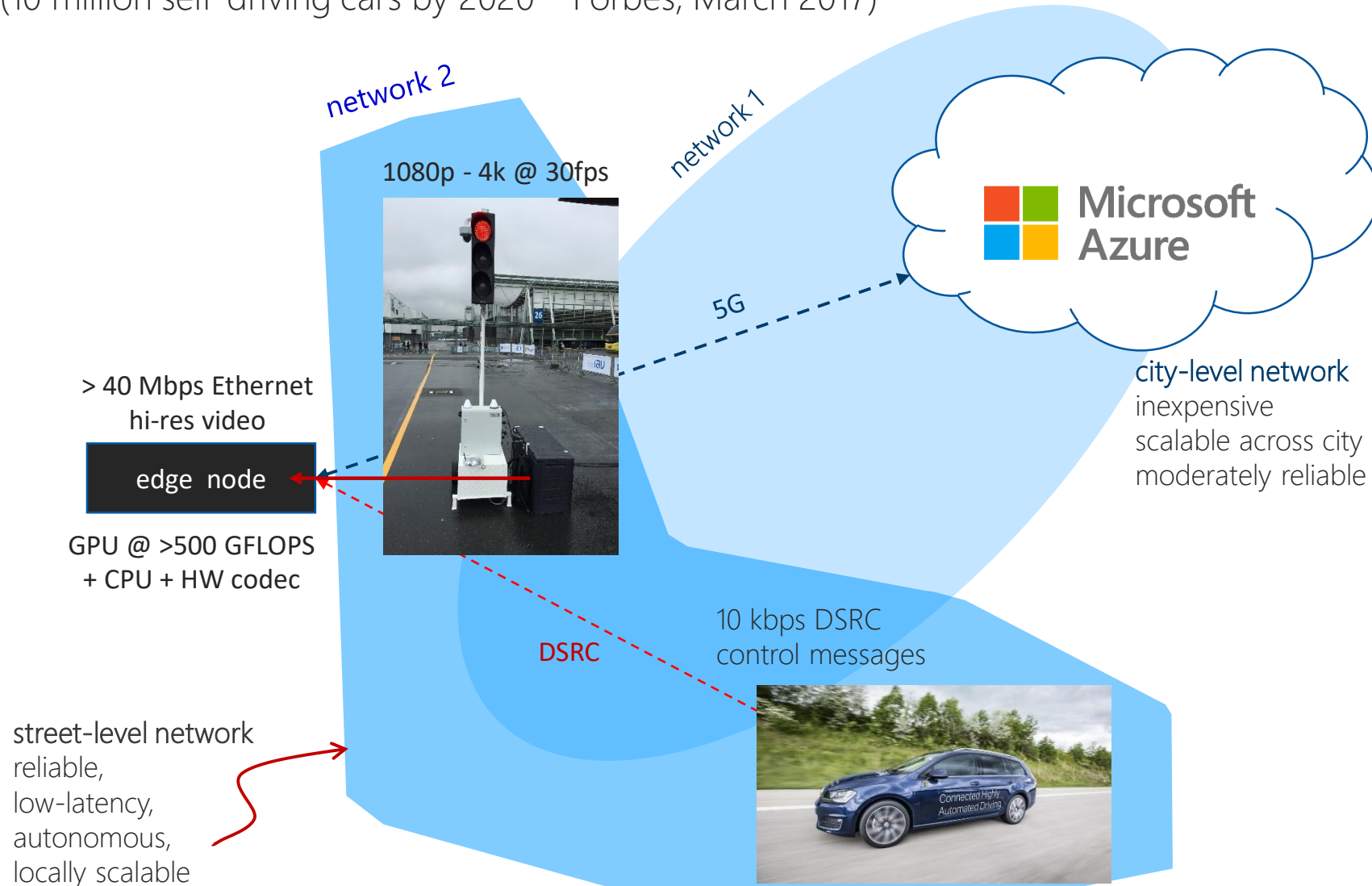


3/8/2019

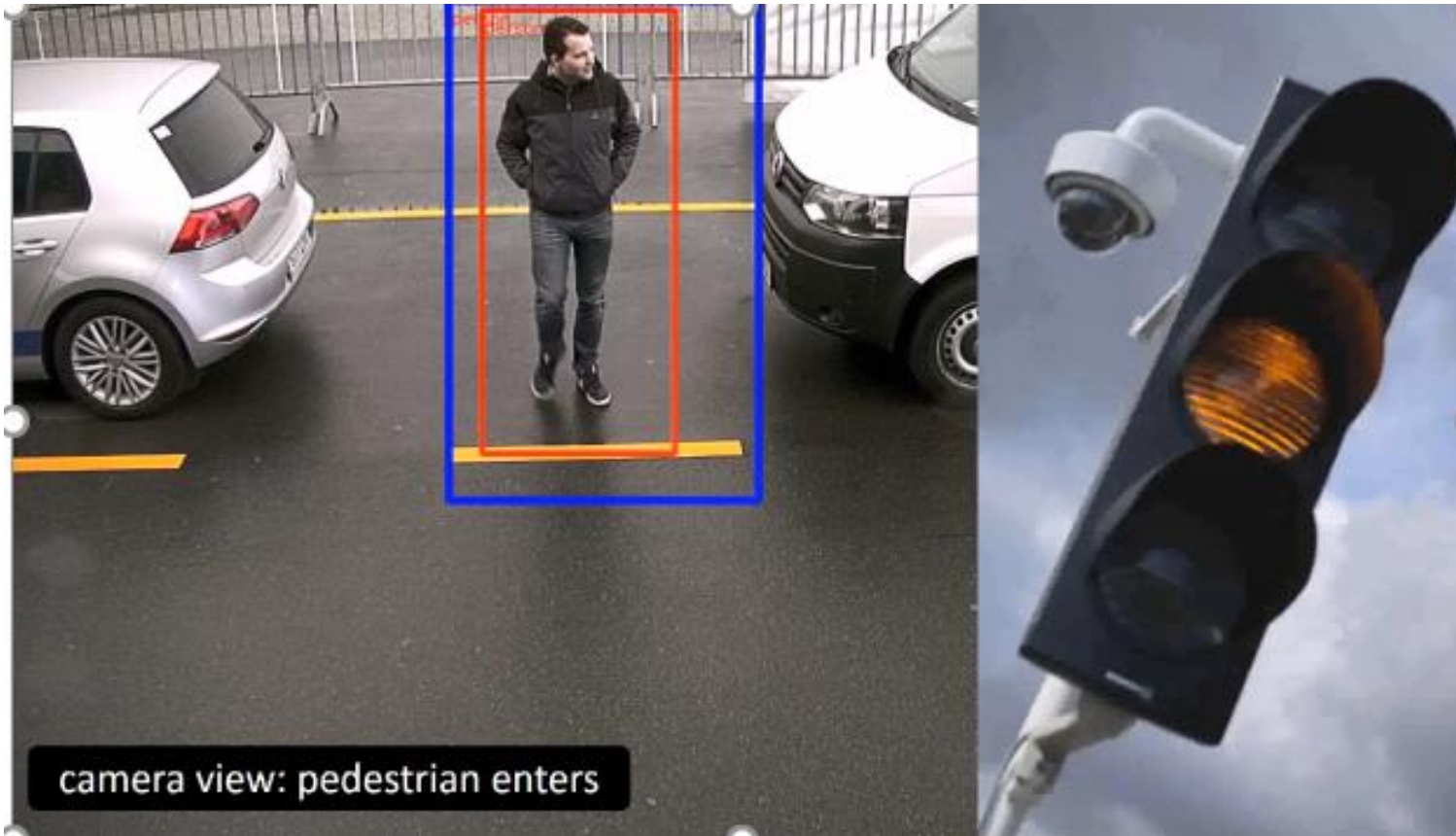
8:07:57.849 AM

# making self-driving cars safer

(10 million self-driving cars by 2020 – Forbes, March 2017)



# live demos in Hannover Messe 2016



# live demos in Hannover Messe 2016

schematic view



# AI for social good

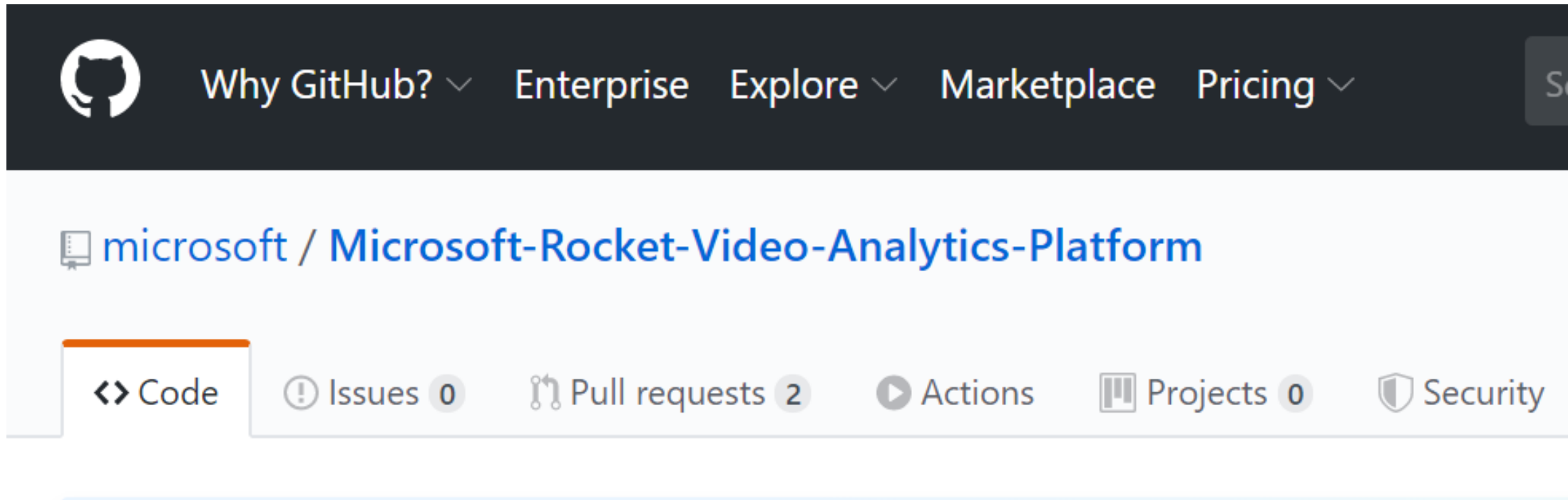


# AI for social good



# MSR Rocket

## An open source video analytics platform



# final remarks

## extracting actionable insights from cameras in the wild

video analytics is infiltrating manufacturing, retail, transportation, telecoms, space explorations, healthcare, ...

- 2022 market projection by \$11.2B (& it is going to change lives)

there are a large # of **systems** challenges in deploying such systems in the wild at scale