ITS Berkeley
Institute of Transportation Studies

ENERGY TECHNOLOGIES AREA

Designing Next Generation Transportation Solutions

Jane Macfarlane
Executive Director
Sustainable Transportation Initiative
Smart Cities Research Center

Research Overview

June 12, 2017

BERKELEY LAB

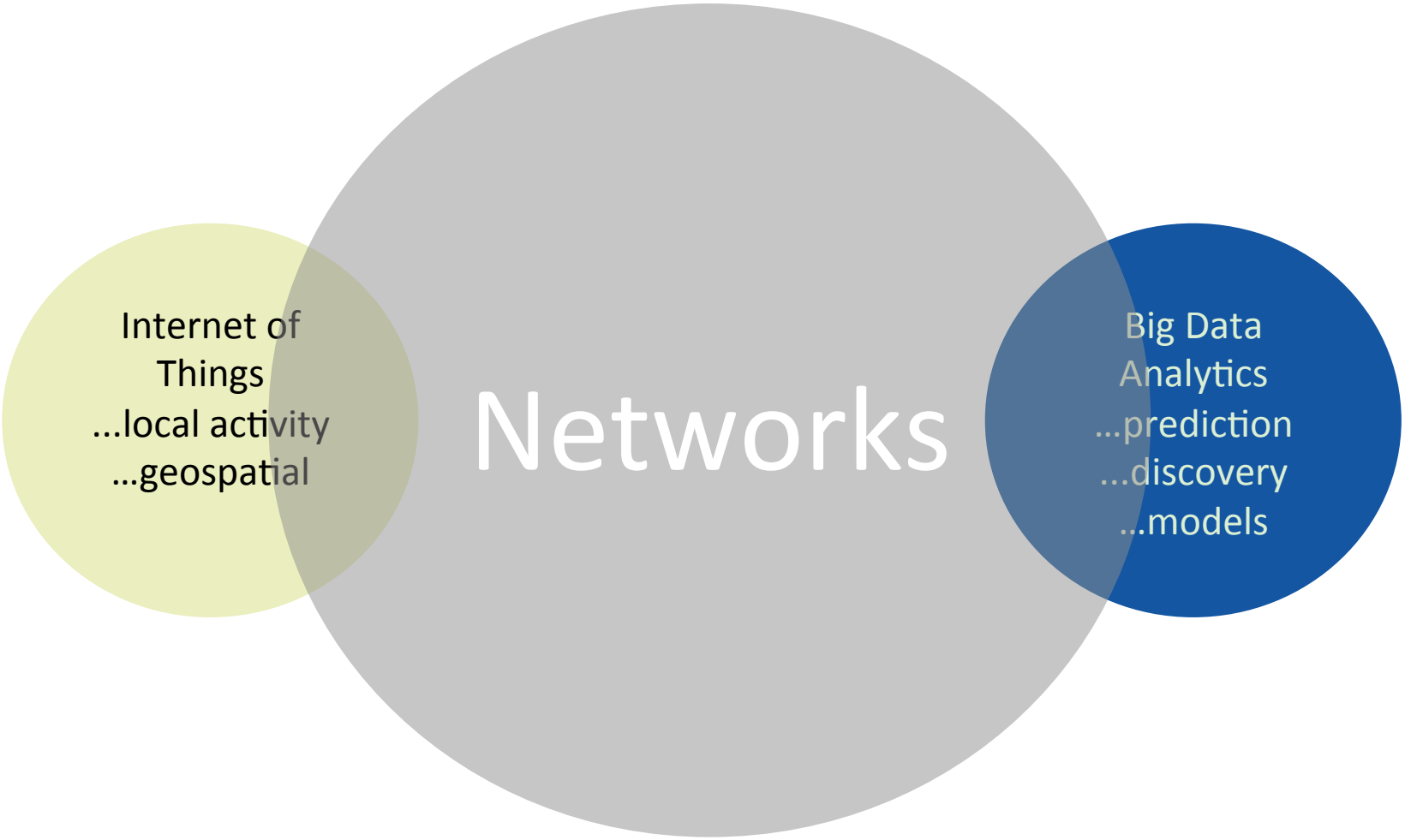
Smart Cities
Research Center

I think that you will all agree that *we are living in most interesting times*. (Hear, hear.) I never remember myself a time in which our history was so full, in which day by day brought us new objects of interest, and, let me say also, *new objects for anxiety*. (Hear, hear.)

Joseph Chamberlain 1898

TRANSFORMATION

CONFLUENCE OF TECHNOLOGIES



SAN FRANCISCO
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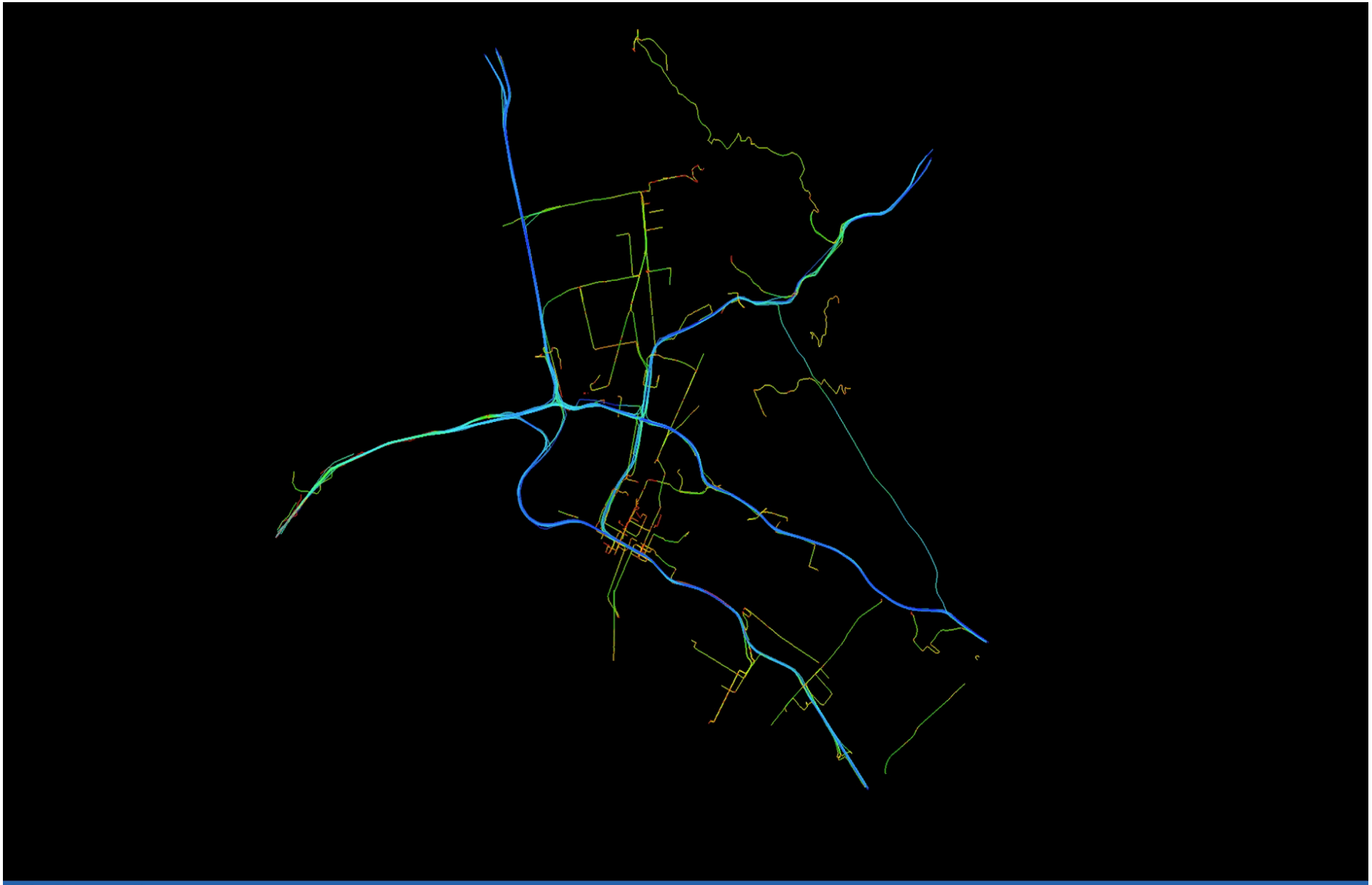

HERE Research

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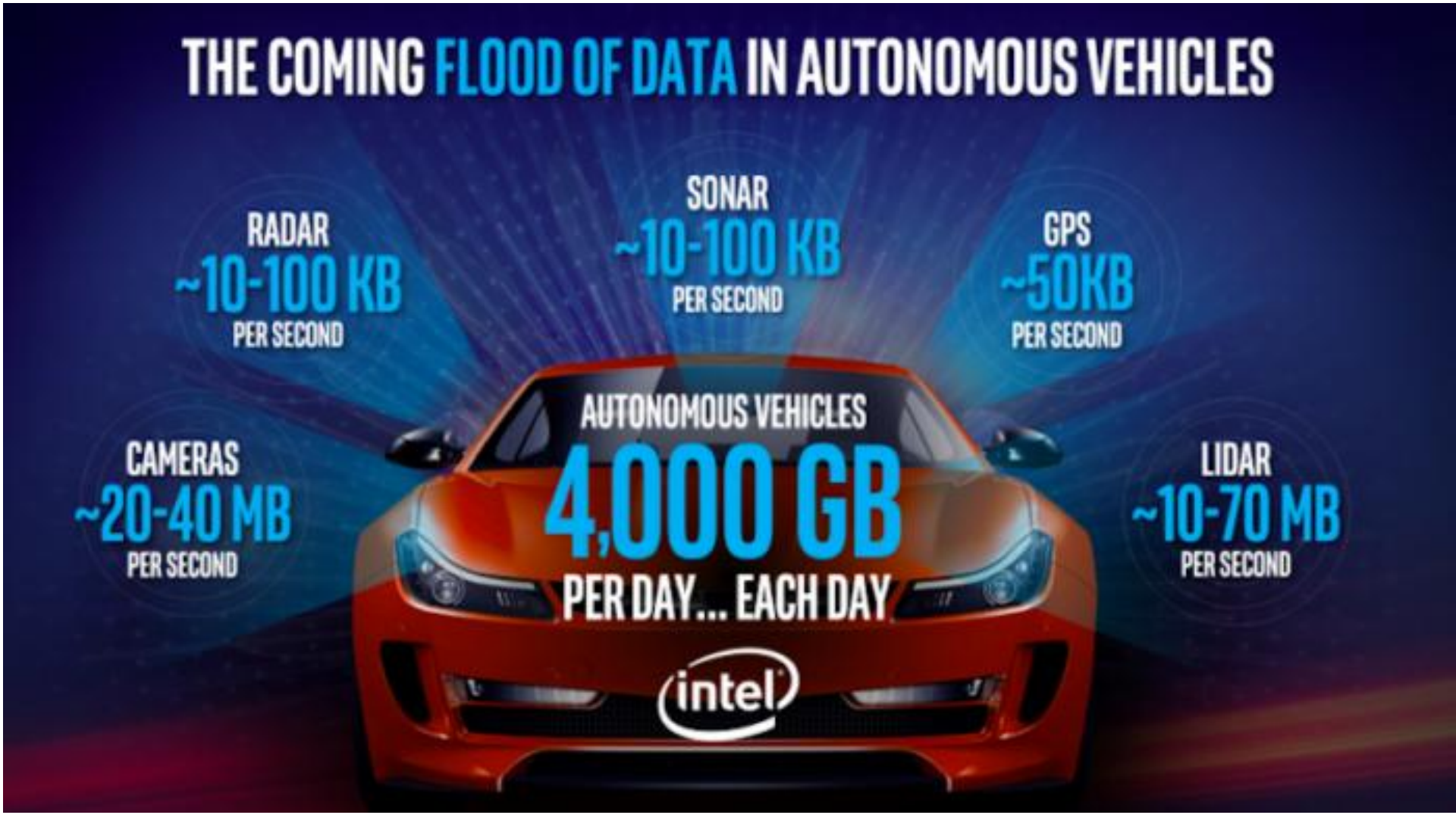
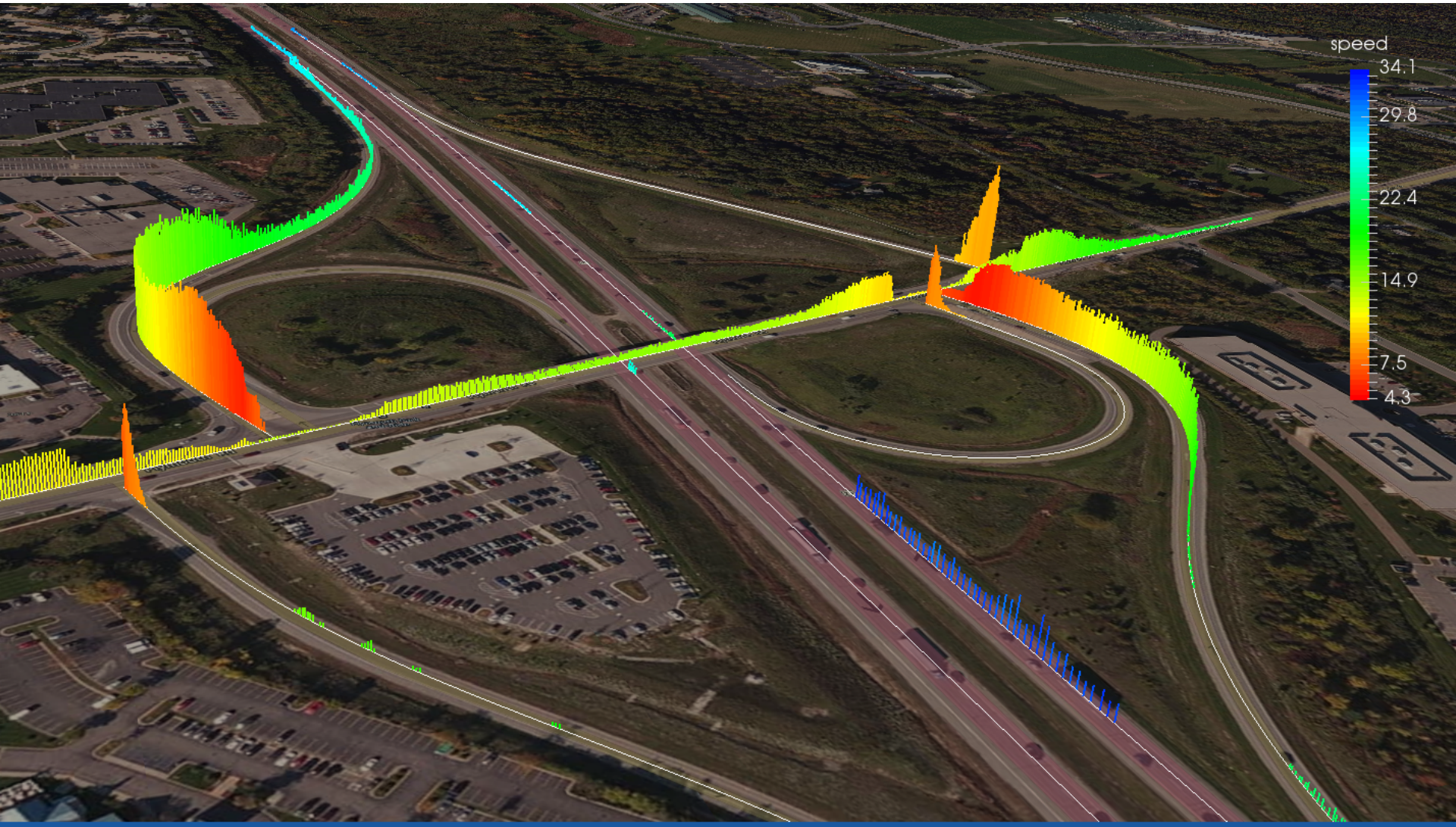
Maps for Life


THE COMING FLOOD OF DATA IN AUTONOMOUS VEHICLES
RADAR
~10-100 KB
PER SECOND
SONAR
~10-100 KB
PER SECOND
GPS
~50KB
PER SECOND
CAMERAS
~20-40 MB
PER SECOND
AUTONOMOUS VEHICLES
4,000 GB
PER DAY... EACH DAY
LIDAR
~10-70 MB
PER SECOND
intel



HERE Research

AUTONOMOUS AERIAL VEHICLES

"Ehang 184 AAV is the safest, Smartest and Eco-Friendly low altitude autonomous aerial vehicle, aiming on providing Medium-Short Distance communication and transportation solution."

Internet of Things Landscape 2016

Applications (Verticals)

Personal

Wearables: WATCH, Samsung Gear 2, pebble, moto g, LG, HUAWEI, CAEDEN, MOTIV, textronics, ORION, Jewelbots, nymi, RINGLY, WEEX

Fitness: JAWBONE, fitbit, TOMTOM, GARMIN, NIKE, MISFIT, BASIS, mi, huami, Microsoft Band, ATLAS, mapmy, fitness, RunKeeper, lumo, amiigo, LifeBEAM, ATHOS, lark, senSoria, WHOOP, striiv

Health: SLEEP, Withings, kinsa, TELCARE, NeuroSky, hale, Thync, beam, QUANTTUS, proteus, Ginger.io, iHealth, EarlySense, XETHRU, nanowear, vessy, beddit, sano, hello, CHRONO, eyeSmart, GLOBAL KINETICS, AdhereTech, AliveCor, PROPELLER HEALTH, Sensor

Entertainment: SONOS, RAZER, doppler labs, ROLI, Narrative, soundhawk, pool, Electric Objects, mural, normal

Family: nucleus, ily, HALO, Glow, OWLET, Good Night Lamp, FiLIP, Rest, bellabeat, monbaby, ovuline, livescribe, LULLY

Sports: STRAVA, WILSON X, Babolat, PELOTON, ZEPP, ARCCOS, INFOMOTION, recon, swingbyte, GOLF, OPEN

Toys: Hasbro, sphero, anki, sifteo, MAKIES, wonder workshop, UBOOLY

Elderly: Healthsense, INDEPENDA, Lively

Home

Automation: nest, LIFX, Honeywell, SAMSUNG, CHAMBERLAIN, iDevices, belkin, wemo, icontrol, SAVANT, ecovent, ecobee, SILVAR, view, LUTRON, ORVIBO, LEVITON, somfy, bluesmart, LIGHT SENTRY, roost, tado°, KEEN

Hubs: nest, amazon alexa, INSTEON, iris, BOSCH, SmartThings, connect, iRule, Control4, ivee, wink, vera, prodea, NINJABLOCKS, Fluent, NEXIA, zonoff

Security: August, SCHLAGE, Kwikset, dropcam, canary, vivint, SimpliSafe, ring, KIWI, LATCH, KeyMe, evercam.io, Lockitron, cocoon, Seek Thermal, scout

Kitchen: JUNE, nomiku, drop, SUPERMECHANICAL, pantry, MOMENTUM MACHINES, BREWBOT, innit, Serenati

Sensing: netatmo, leeo, ambient, birdi, AWAIR, CUBESENSORS, wally HOME, sense, TRANSFORMAIR

Consumer Robotics: ALDEBARAN, jibo, iRobot, RobotsLAB

Pets: Whistle, Petnet, HACHIKO, Petcube, FitBark

Garden: EDYN, plantlink, BITPONICS, rachio

Trackers: tile, iotera, Athentek, TrackR

Vehicles

Automobiles: INRIX, waze, AUTOMATIC, STREETLINE, dash, Zubie, navdy, Automile, vinli, Airbiquity, censio, OpenXC, CobaltHandler

Autonomous: Google Self-Driving Car Project, audi, GM, TESLA, DAIMLER, UBER, CRUISE, Ford, QUANERGY, DELPHI, NOVARIANT, nuTonomy, Peloton, Mobileye, Valeo

UAVs: dji, 3DR, Parrot, Airware, LILY, CyPhy, SKYCATCH, SKYDIO, YUNEEC, DRONE BASE, DroneDeploy, HEXO+, DRL

Space: BOEING, LOCKHEED MARTIN, AIRBUS DEFENCE & SPACE, SPACEX, BLUE ORIGIN, spire, Orbital ATK, NANORACKS, BALLISTIC, XCOR

Bicycles / Motorbikes: sobi, HAMMERHEAD, superpedestrian, gogoro, SKULLY, SKYLOCK

Enterprise

Healthcare: STANLEY, AUGMEDIX, VERSUS, mcio, vitalconnect, NovaSom, mim, Senseonics, PEERBRIDGE, vivify, AIRSTRIP, Sotera, Rhythm, Monica, INFOBIONIC, TeleTracking, PNEUMOCARE, PRISTINE, VivaMetrics, ORTHOSENSOR

Retail: RETAILNEXT, euclid, Theatro, PRISM SKYLABS, hiku, cloudtags, GIMBAL, PHUNWARE, NOMI, VARIABLE

Payments / Loyalty: PayPal, shopify, Square, Verifone, payleven, belly, coin, cantaloupe, acs, SHOPKEEP, ciright, LevelUp, DUALI

Smart Office: LogMeIn, CRESTRON, kisi, Robin, BUILDING ROBOTICS, CLEAR, CBRE, XORA, eventboard

Agriculture: JOHN DEERE, adapt-N, Ag Leader, ONFARM, pycno, ARQUS, DACOM, Smartfield, afimilk, Zedx, ClimateMinder, SPENSA, SMART FARM, i-Linc

Infrastructure: WORLD, SENSING, TACHYUS, mPrest, ELTAV, Smart Cloud, M2M communications, INCON, SMARTSTRUCTURES, LUMASENSE TECHNOLOGIES, SensorLogic, GROUNDMETRICS

Industrial Internet

Machines: CATERPILLAR, SIEMENS, BOSCH, GE, SIGHT MACHINE

Energy: Schneider Electric, Itron, enlighted, SolarCity, BAKER HUGHES, Trilliant, enevo, ENERNOC, igolady, SMART CITY CLUSTER, OSIsoft, enbala, e-on, EnergyHub, lucid, Silver Spring, ENERGYSAVVY, HydroPoint, sensity, Blue Pillar, AutoGrid, Panoramic, DETRA SYSTEMS, fat Spaniel

Supply Chain: Fleetmatics, Impinj, VILOC, Omni-ID, SkyBitz, SMARTDRIVE, Telogis, assetpulse, WEFT, TEGO, ZEBRA, PRECYSE, RF CONTROLS

Robotics: amazon robotics, ABB, CLEARPATH, HARVEST, rethink robotics, Boston Dynamics, KUKA, RobotsX, EMPIRE, LIQUID ROBOTICS, tempo automation, OPENROV

Industrial Wearables: GLASS, DAQRI, parsable, humancondition, BITSTEW, GUARDHAT, XOEYE TECHNOLOGIES, wavelink, APX

Platforms & Enablement (Horizontals)

Platforms

Software: xively, GE, Axeda, Jasper, Ayla Networks, ThingWorx, Numerex, seeeo, M2M SPECTRUM NETWORKS, wot.io, davra networks, ZATAR, covisint, AUTODESK SEECONTROL, PubNub, thingsquare, BSQUARE, greenwave systems, M2M OPERATIONS NETWORKS, WiSilica, innoPath, peoplepower, machineshop, IoT, arrayent

Full Stack: samsara, EUROTECH, Predix, HELIUM, Telit

Developer: electric imp, TESSEL, resin.io, TEMBOO, Particle, theThings.iO, KONEKT, SensorCloud, NewAer

Analytics: splunk>, sumologic, STRATOSCALE, iobeam, KAAZING, TempoQ, UPTAKE, glassbeam

Sensor Networks: placemeter, SAFECAST, SST, MotionLoft

Connectivity: SIGFOX, SIERRA WIRELESS, neul, FILAMENT, aeris, GENU, VENIAM, KORE, intamac, skyroam, ARKESSA, senet, actility

Security: Symantec, gemalto, Bastille, inside, MOCANA, NEURA, SHODAN, escrypt, SecuriThings, CyberFlow, OWASP

Open Source: KAA, ThingSpeak, iot, webinos, openHAB, nimbits

Interfaces

Virtual Reality: oculus, VIVE, PlayStation VR, Samsung Gear VR, OSVR, AVEGANT

Augmented Reality: Microsoft HoloLens, magic leap, Meta, SONY, blippar, zSpace, VUZIX, EPSON, PARACOSM

Other: amazon alexa, THALMIC, nod, EMOTIV, LEAP MOTION, SIXENSE, ivee, RYTHM, omni, api.ai

3D

Printing / Scanning: BODYSYSTEMS, Project Tango, intel REALSENSE, stratasys, occipital, OMC, VOLTERA, matterport, formlabs, DESKTOP METAL, XYZ, Carbon, BotFactory, shapeways, sculpteo, VOODOO MANUFACTURING

Content / Design: Sketchfab, Thingiverse, GRABCAD, AUTODESK, BODY LABS, FLOORED, DASSAULT SYSTEMES

Building Blocks

Hardware

Processors / Chips: intel, QUALCOMM, TOSHIBA, TEXAS INSTRUMENTS, Atmel, ARM, NVIDIA, LG, SIEMENS, NXP, SILICON LABS, Movidius

Sensors: NXP, Atmel, TEXAS INSTRUMENTS, NATIONAL INSTRUMENTS, libelium, psikick, Qualtré, MEMSIC, VALENCELL, PetaSense, XERAFY, skytek, mCube, MOOG, ThingMagic

Parts / Kits: ARDUINO, Raspberry Pi, littleBits, Octopart, XILINX, relayr, adafruit

Charging: uBeam, WiTricity, humavox, AMPY

Software

Cloud: Google Cloud Platform, cisco, IBM Watson IoT Platform, Microsoft Azure, amazon web services

Mobile OS: iOS, android, Brillo, HomeKit, BlackBerry

Connectivity

Protocols: WiFi, Bluetooth, ZigBee Alliance, LoRa Alliance, XMPP, MQTT, NFC, Z-WAVE, AMQP, M-Bus, oma, MiWi, X10, THREAD, HART, BITX, DDS, RFID, CoAP, RuBee, 2G 3G 4G LTE 6LoWPAN LWM2M DDS LIDAR

M2M: intel, QUALCOMM, MARVELL, BROADCOM, SIEMENS, PowerWave, TEXAS INSTRUMENTS, Atmel, Laird, cisco, MOTOROLA, Fibocom, goTenna, GainSpan, ocean, altair, Weaved

Telecom: verizon, atat, 中国移动 China Mobile, T-Mobile, Sprint, airtel, orange, Telefónica, China UNICOM, americamovil, US Cellular, vodafone

WiFi: eero, STARRY, BRCK, Open Garden

Consultants / Services

IDEO, d Dragon Innovation, MESH SYSTEMS, PTC, pch, R/GA, 3D HUBS, ISL, makexyz, altiux, 8

Alliances: ALLSEEN ALLIANCE, oma, Industrial Internet Consortium, AIOTI, Internet of Things Consortium, OPEN CONNECTIVITY FOUNDATION

Partners

Retail: amazon, Walmart, BEST BUY, apple, NEW BALANCE, TARGET, LOWE'S

Manufacturing: FOXCONN, flex, SANMINA, JABIL, PEGATRON, Benchmark, Celestica

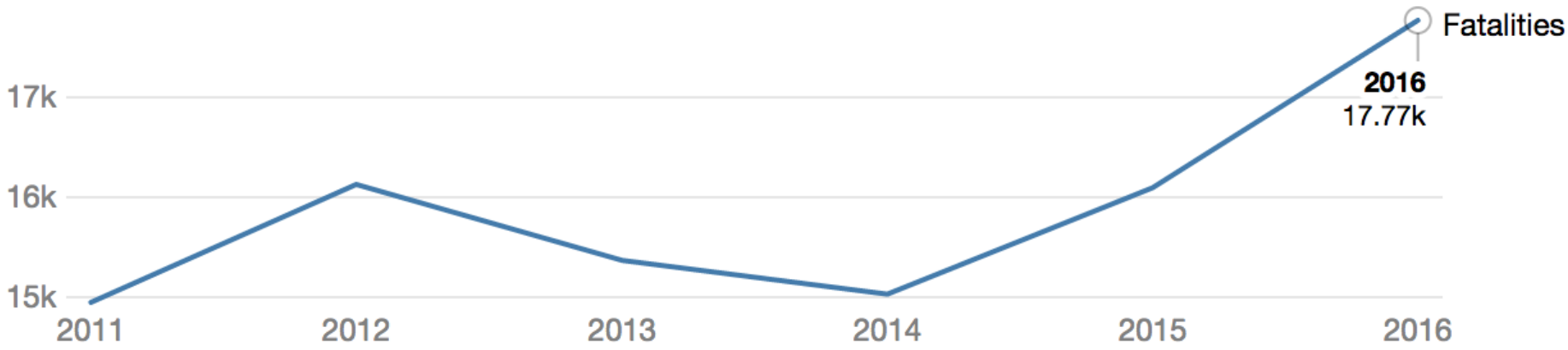
Incubators: techstars, Highway1, HAX, LEMNOS Labs, BOLT

Funding: KICKSTARTER, INDIEGOGO, AngelList

© Matt Turck (@mattturck), David Rogg (@davidjrogg) & FirstMark Capital (@firstmarkcap)

FIRSTMARK

Fatalities in car crashes between January and June



Source: National Highway Traffic Safety Administration Get the data

Vehicle is NOT a Consumer Device

"He said, 'I'm sorry, I'm sorry. I was texting.' I said, 'Son, do you know what you just did?' He said, 'I'm sorry. I'm sorry,'" Kuchler recalled.

CORE OPPORTUNITY

Explore untapped system-level efficiencies at planning and operations timescales

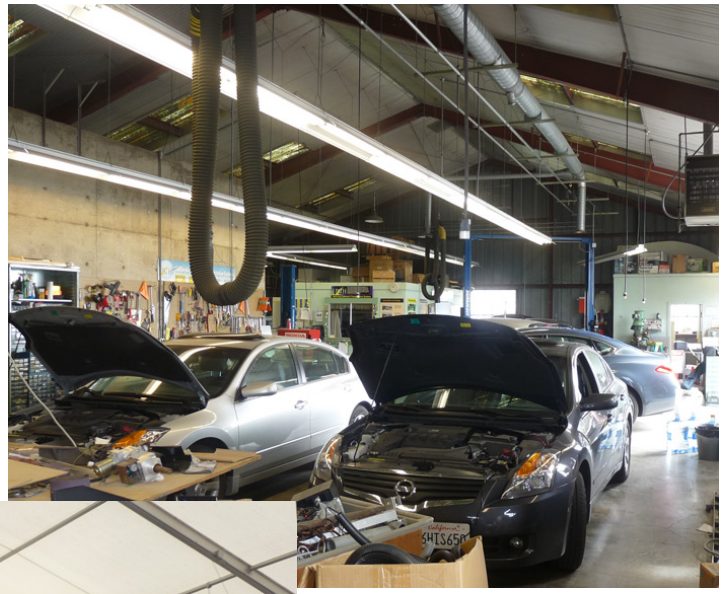
Today:

- Vehicle-level focus
- Independent
- Unconnected
- Subject to behaviors & decisions

Tomorrow:

- System-level focus
- Connected
- Automated
- In concert
- Across modes
- Managed behaviors & decisions
- Agencies working together (energy, safety, mobility)

FACILITIES ON BERKELEY CAMPUS AND RICHMOND FIELD STATION



CROSS CUTTING EXPERTISE IN VEHICLE TECHNOLOGIES

Hierarchical architecture to simplify design and development of automation systems

Model and simulation tools for evaluating design

High performance automated test vehicle – light and heavy duty

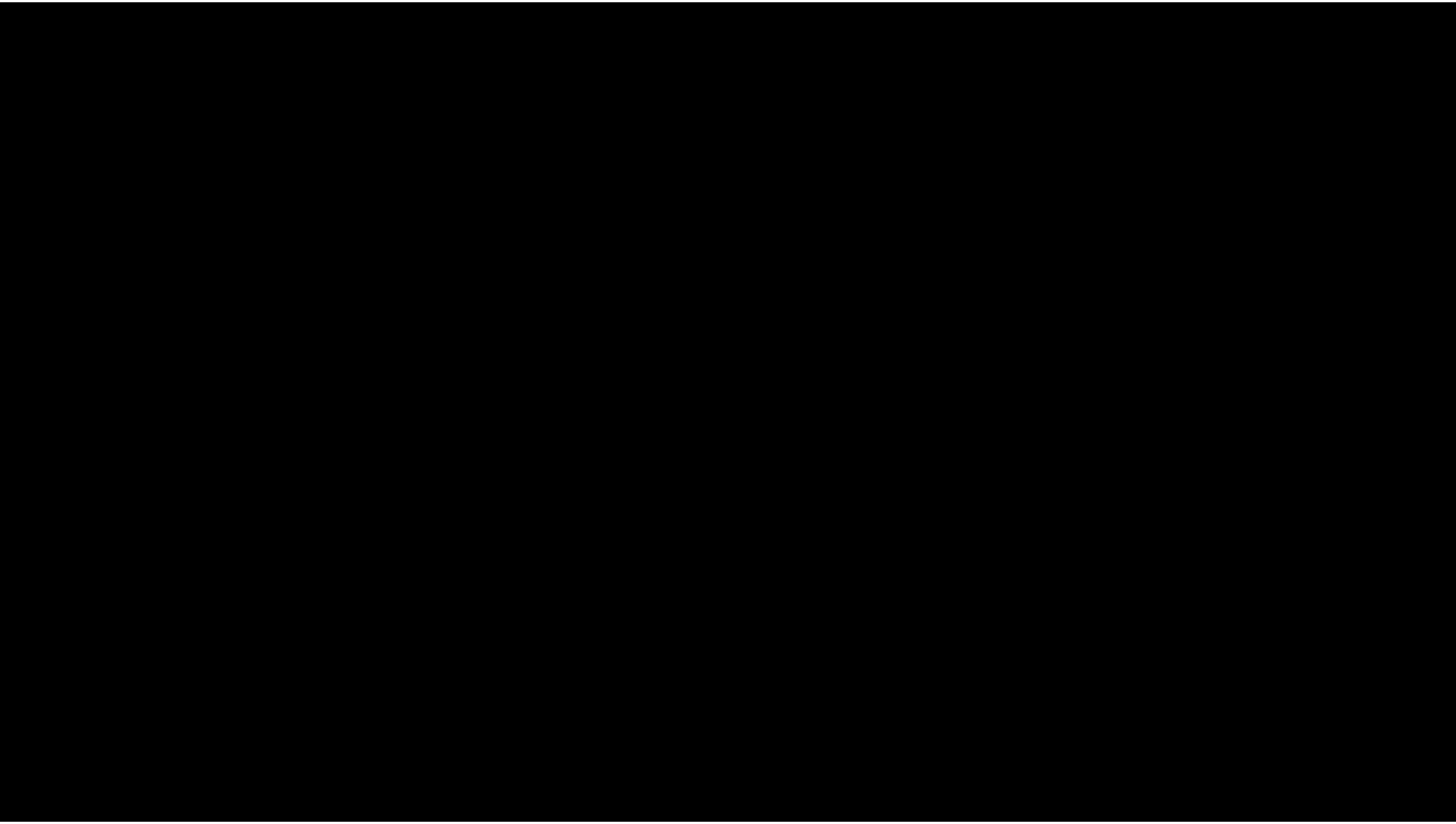
High accuracy vehicle control with a focus on passenger comfort

AUTOMATED PLATOON LONGITUDINAL CONTROL AND MERGING

Consistent , accurate steering on the highway, 3 cm lateral variations at highway speed

Merging allows vehicles join passing platoons

VOLVO GROUP COLLABORATION ON TRUCK PLATOONING



ADDITIONAL RESEARCH

Cooperative Adaptive Cruise Control

Transit Bus Precision Docking

Vehicle Assist and Automation

Advanced Traffic Signal Control

Eco-Driving

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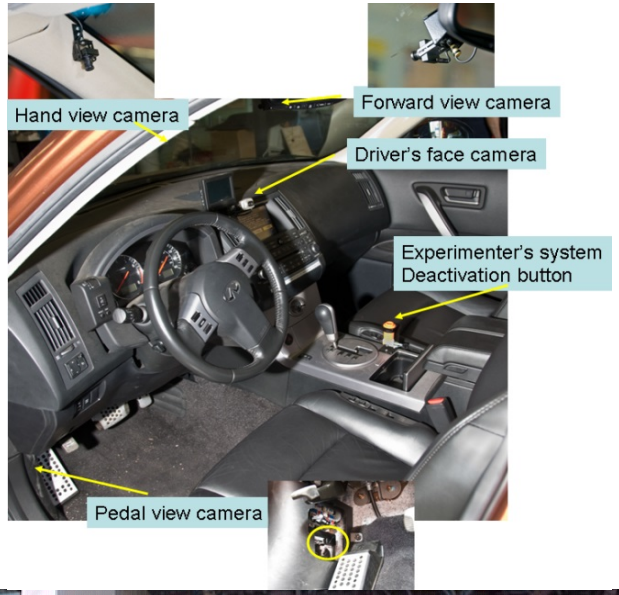
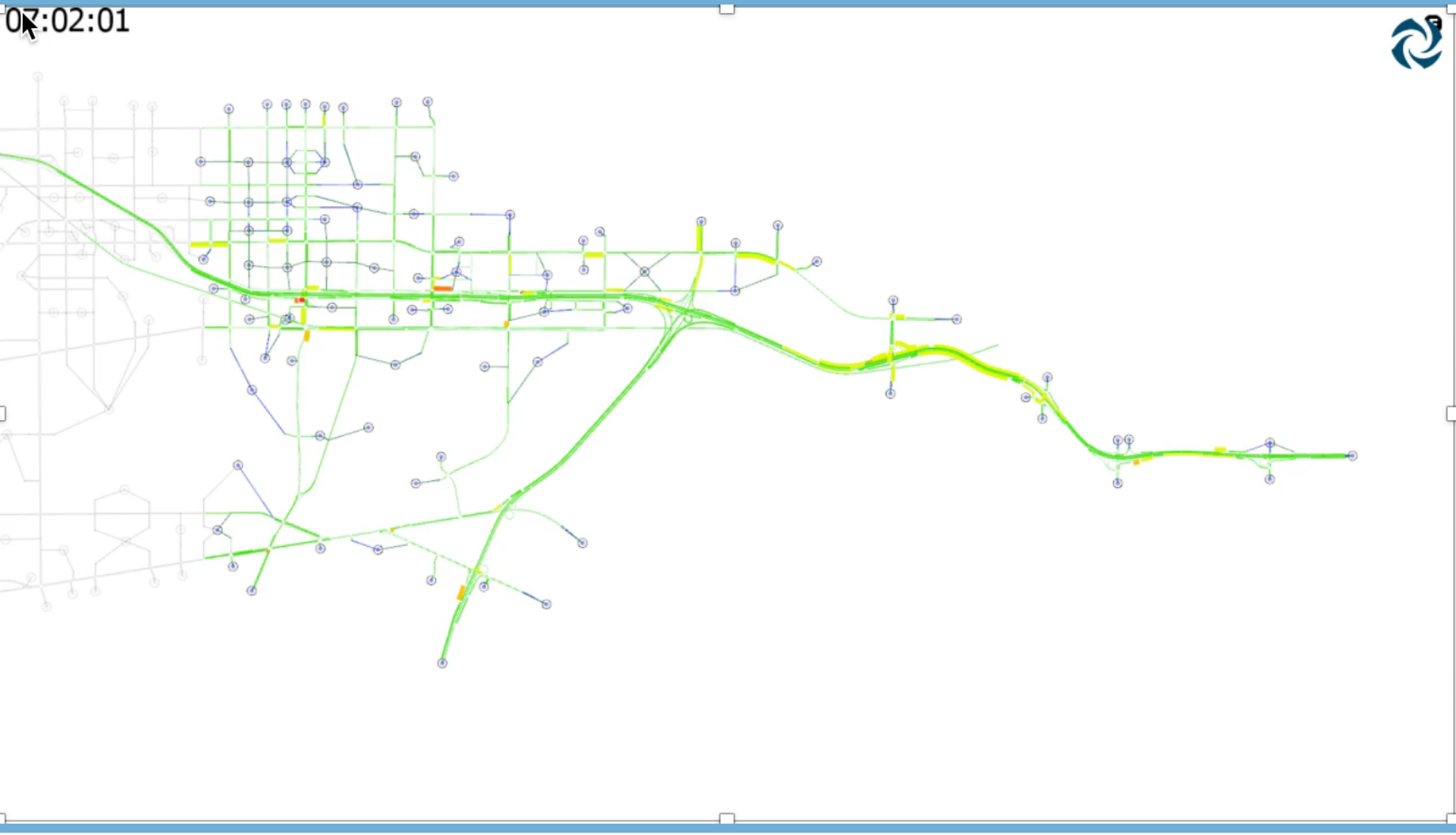


EXAMPLE I210 (LOS ANGELES)

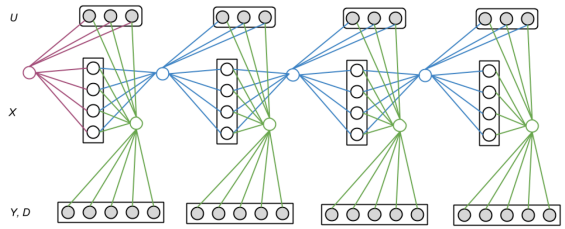


ESTIMATED BENEFITS OF CORRIDOR MANAGEMENT

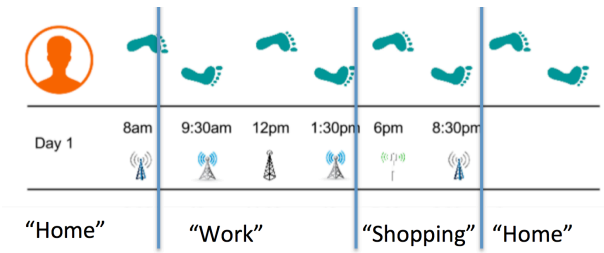
	San Diego	Dallas	Minneapolis
Annual Travel Time Savings (Person-Hours)	246,000	740,000	132,000
Improvement in Travel Time Reliability (Reduction in Travel Time Variance)	10.6%	3%	4.4%
Gallons of Fuel Saved Annually	323,000	981,000	17,600
Tons of Mobile Emissions Saved Annually	3,100	9,400	175
10-Year Net Benefit	$104M	$264M	$82M
10-Year Cost	$12M	$14M	$4M
Benefit-Cost Ratio	10:1	20:1	22:1

TOP DOWN CONTROL

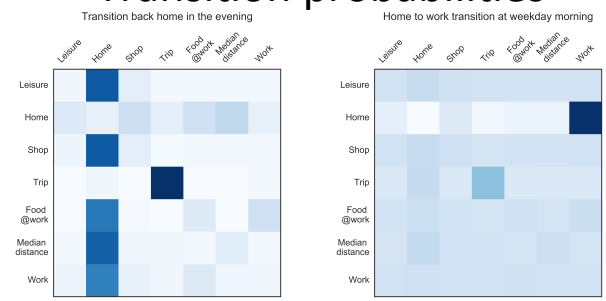
ACTIVITY-BASED DEMAND WITH MACHINE LEARNING



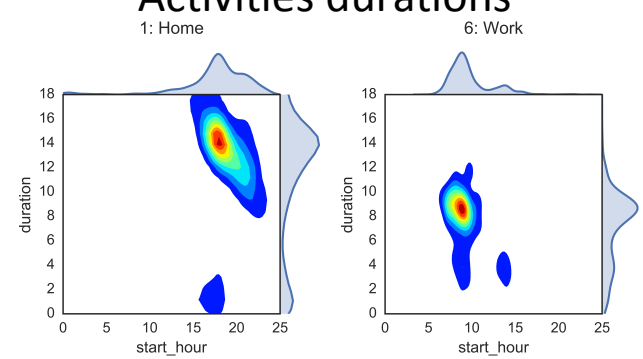
NN-HMM Architecture



Transition probabilities



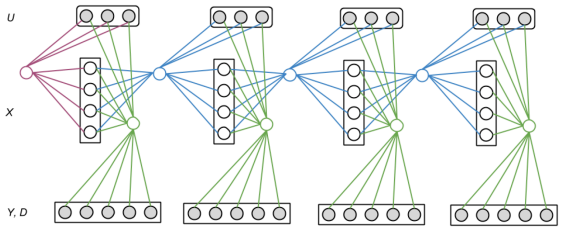
Activities durations



Human activity recognition from sequential location data with generative machine learning models:

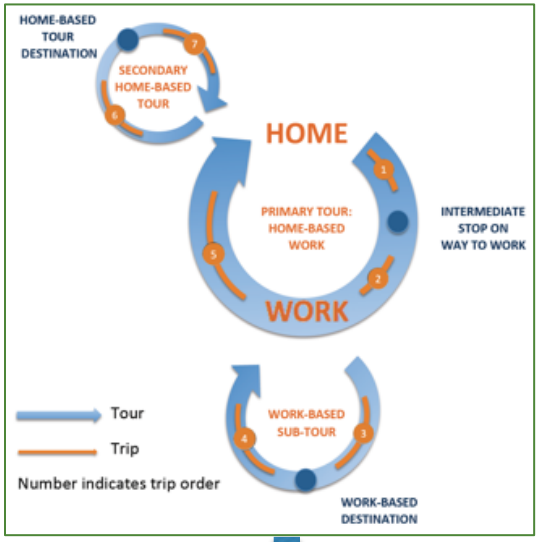
- Recognize activity states (fit model structure with hidden variables)
- Learn daily activity pattern (conditional transition probabilities)
- Learn models for observable variables (destination choices and durations of activities given space/time context)

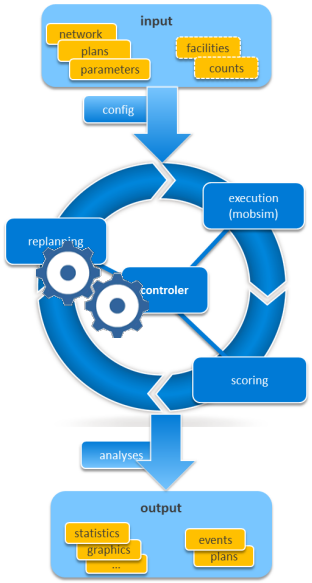
San Francisco Bay Area mobility simulation from cellular data



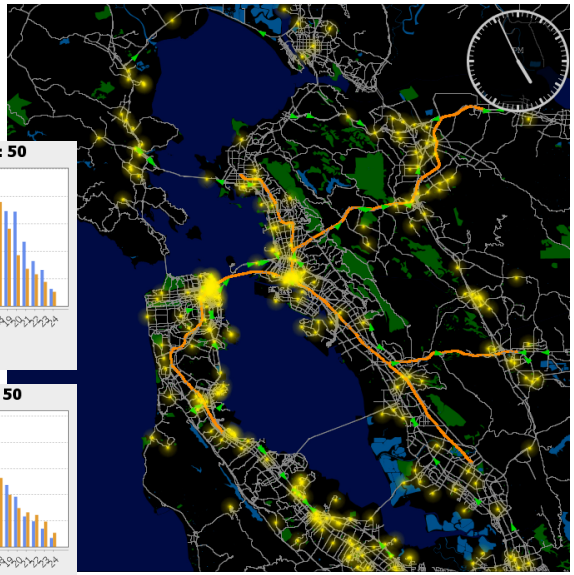
NN-HMM Architecture

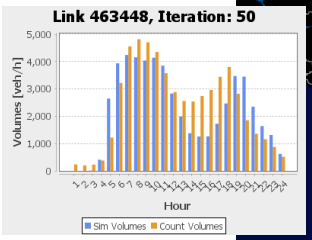
Learn travel demand model for a population

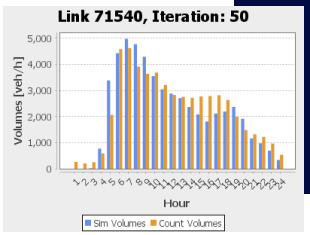




1M agents, 500 shown in visualization

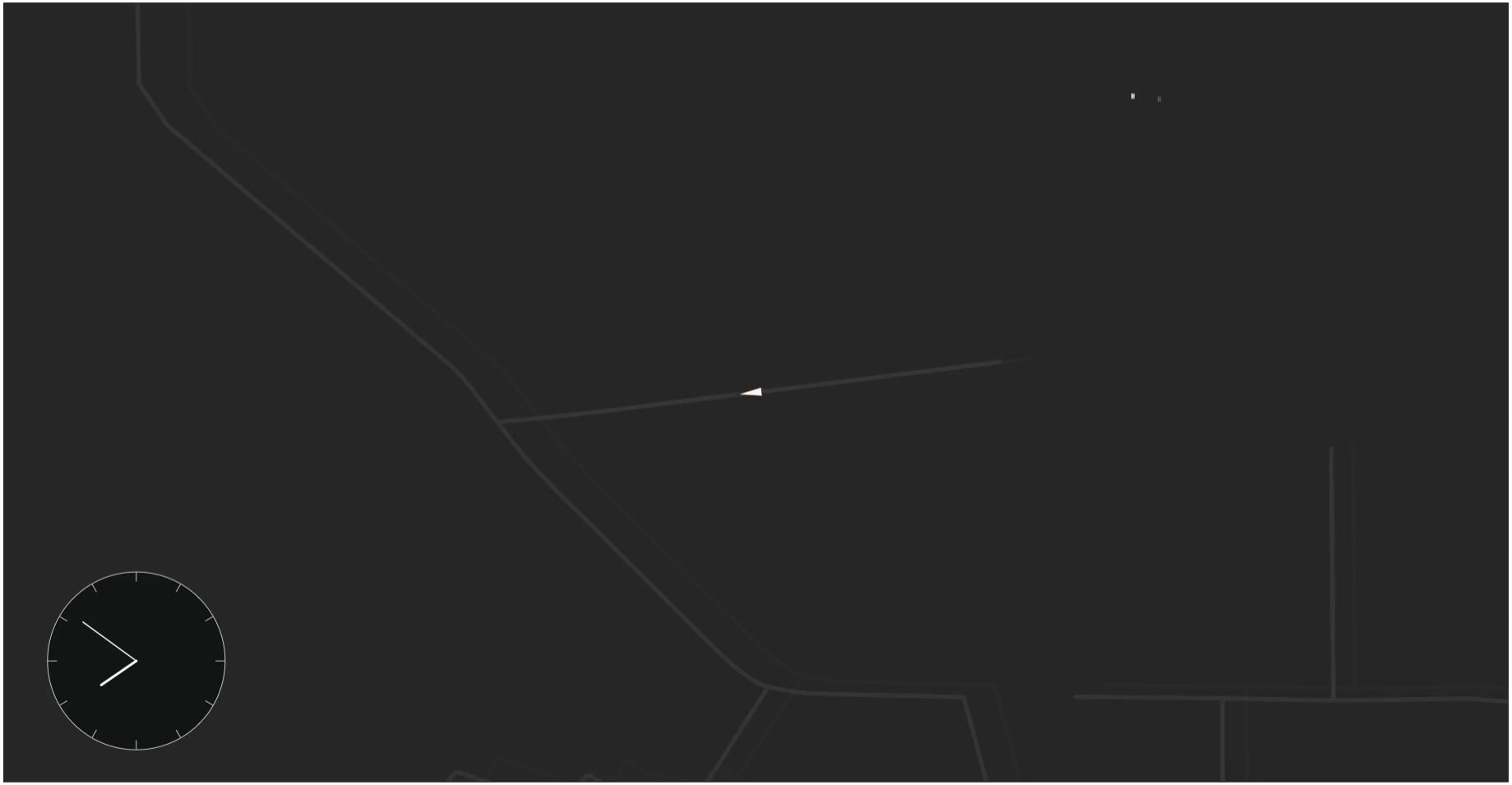






Run regional mobility simulation scenarios

INFRASTRUCTURE PLANNING FOR ALTERNATIVE FUEL VEHICLES

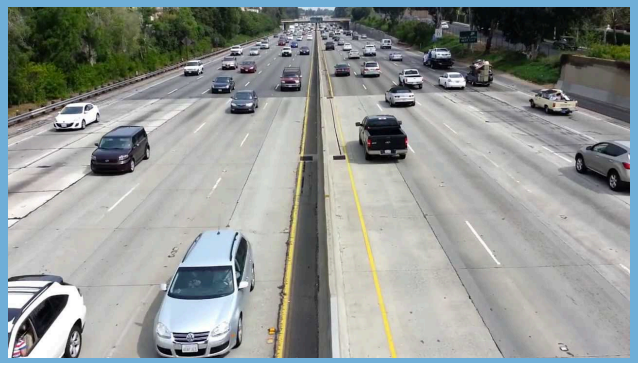


CURRENTLY BOTTOM UP SOLUTIONS

NEED TO BE BALANCED BY TOP DOWN SOLUTIONS

SMART Mobility Program by DOE

- Mobility Decisions
- Urban Science
- Infrastructure Requirements
- Multi-Modal Solutions
- Vehicles of the Future (CAV)

Reduce Transportation Demand

Increase System Efficiency