



COLORADO

Department of
Transportation



**Road Profile Users' Group
November 15, 2017**

FY 2016-2017
\$1.44 Billion Budget



CDOT RESPONSIBILITIES

ADMINISTERS
\$208
MILLION
EACH YEAR IN FEDERAL
GRANTS

3,454

BRIDGES

CDOT
MAINTAINS & OPERATES
23,000

TOTAL
LANE MILES
OF HIGHWAY



**DIVISION OF
TRANSIT
AND RAIL**
ADMINISTERS FED/STATE
GRANTS AND OPERATES
BUSTANG

6.1 MILLION
MILES
PLOWED
OF SNOW PER YEAR 

35 MOUNTAIN
PASSES
OPEN YEAR-ROUND 

**AIRPORT
PLANNING**
INTERFACE WITH FAA 

Source: Colorado Department of Transportation, 2014

Purpose

To save lives and make lives better by providing freedom, connection and experience through travel.



Values

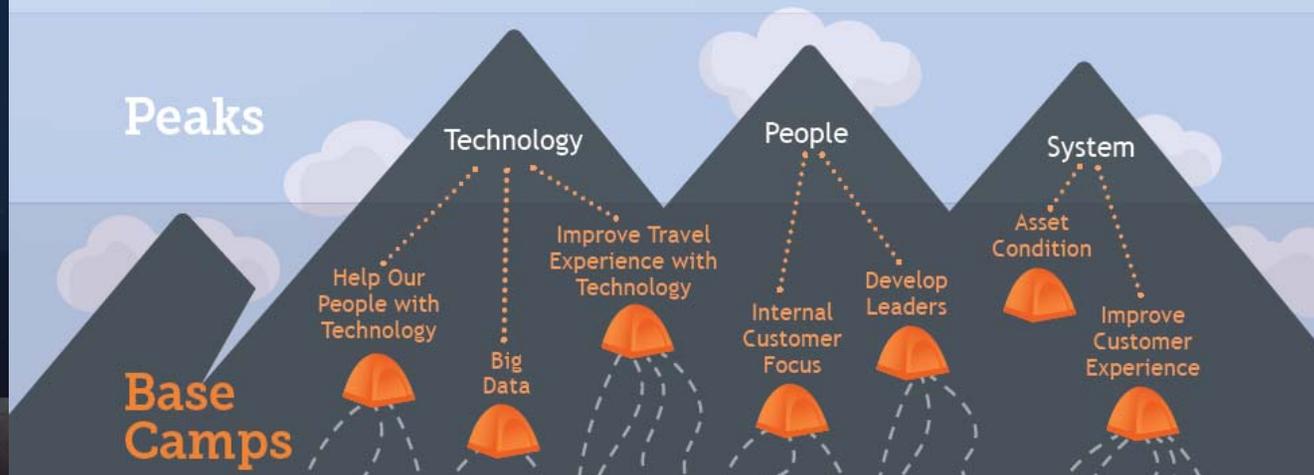
Safety, people, integrity, customer service, excellence and respect are at the heart of all that we do.

Summit

The best DOT in the country for all customers by focusing on our people, leading-edge technology and a healthy multi-modal system.

Peaks

Base Camps



OUR CHALLENGE

Continued Growth



1991



3.3 million



27.7 billion
vehicle miles traveled

\$
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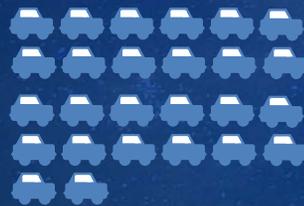
\$125.70

spent per person

2015



5.4 million



50.5 billion
vehicle miles traveled

\$
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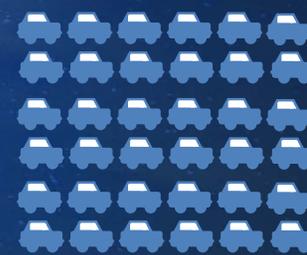
\$68.94

spent per person

2040



7.8 million



72.3 billion
vehicle miles traveled

\$

\$41.16

spent per person

*All dollar
figures
adjusted
for inflation*

 | **ROADX**
ACCELERATING TECHNOLOGY

RoadX **VISION**: Crash-free, Injury-free, Delay-free and Technologically-transformed travel in Colorado.

RoadX **MISSION**: Team with public and industry partners to make Colorado one of the most technologically advanced transportation systems in the nation, and a leader in safety and reliability.

Colorado Is Open For Business – Colorado invites partners to join us in accelerating the adoption and deployment of technological solutions.



Why do we need to act?

SAFETY

80% reduction in crashes per NHTSA estimates



MOBILITY

40 to 400% increase in capacity





5 levels of driving automation

		Steering and acceleration/ deceleration	Monitoring of driving environment	Fallback when automation fails	Automated system is in control
Human driver monitors the road	0 NO AUTOMATION				N/A
	1 DRIVER ASSISTANCE				SOME DRIVING MODES
	2 PARTIAL AUTOMATION				SOME DRIVING MODES
Automated driving system monitors the road	3 CONDITIONAL AUTOMATION				SOME DRIVING MODES
	4 HIGH AUTOMATION				SOME DRIVING MODES
	5 FULL AUTOMATION				



Highly
Automated
Vehicles
(HAVs)

Human driver
 Automated system

NHTSA's AV Guidance and ODD

The document identifies **Operational Design Domain (ODD)** as the critical definition of where (such as what roadway types, roadway speeds, etc.) and when (under what conditions, such as day/night, normal or work zone, etc.) an HAV is designed to operate. The importance of communicating the ODD of an HAV to the consumer as part of broader product education is highlighted.

		Steering and acceleration/ deceleration	Monitoring of driving environment	Fallback when automation fails	Automated system is in control
3	CONDITIONAL AUTOMATION				SOME DRIVING MODES
4	HIGH AUTOMATION				SOME DRIVING MODES

Connected road classification system

Level
1

Unpaved and/or non-stripped roads designed to a minimum level of standard of safety and mobility

Level
2

Paved roads designed to AASHTO's standards with MUTCD signage. There is not Intelligent Transportation System (ITS) equipment or infrastructure to collect connected vehicle data (Dedicated Short Range Radio). Access to cellular data service may be available

Level
3

There is Intelligent Transportation System (ITS) equipment operated by a Traffic Operation Center (TOC) and/or, one way electronic data share between DOT/Vehicle/User and/or, mixed use lanes



Connected road classification system

Level
4

Roadway or specific lane(s) has adaptive ITS equipment (i.e. smart signals hold for vehicles, highway lighting that turn on for vehicles, etc.) with Traffic Operations Center override only, and/or two way data share between DOT/Vehicle/User, and/or lanes designated for vehicle levels 3 & 4 only

Level
5

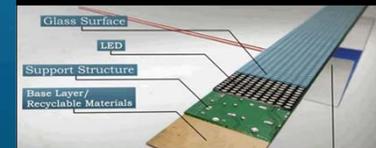
(Advance Guide-way System) roadway or specific lane(s) designed for vehicle level 4 only with additional features that may include inductive charging, advance/enhanced data sharing, etc. Additionally, no roadside signs are needed as all roadway information is direct to vehicles' on-board systems

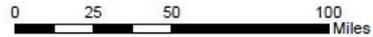
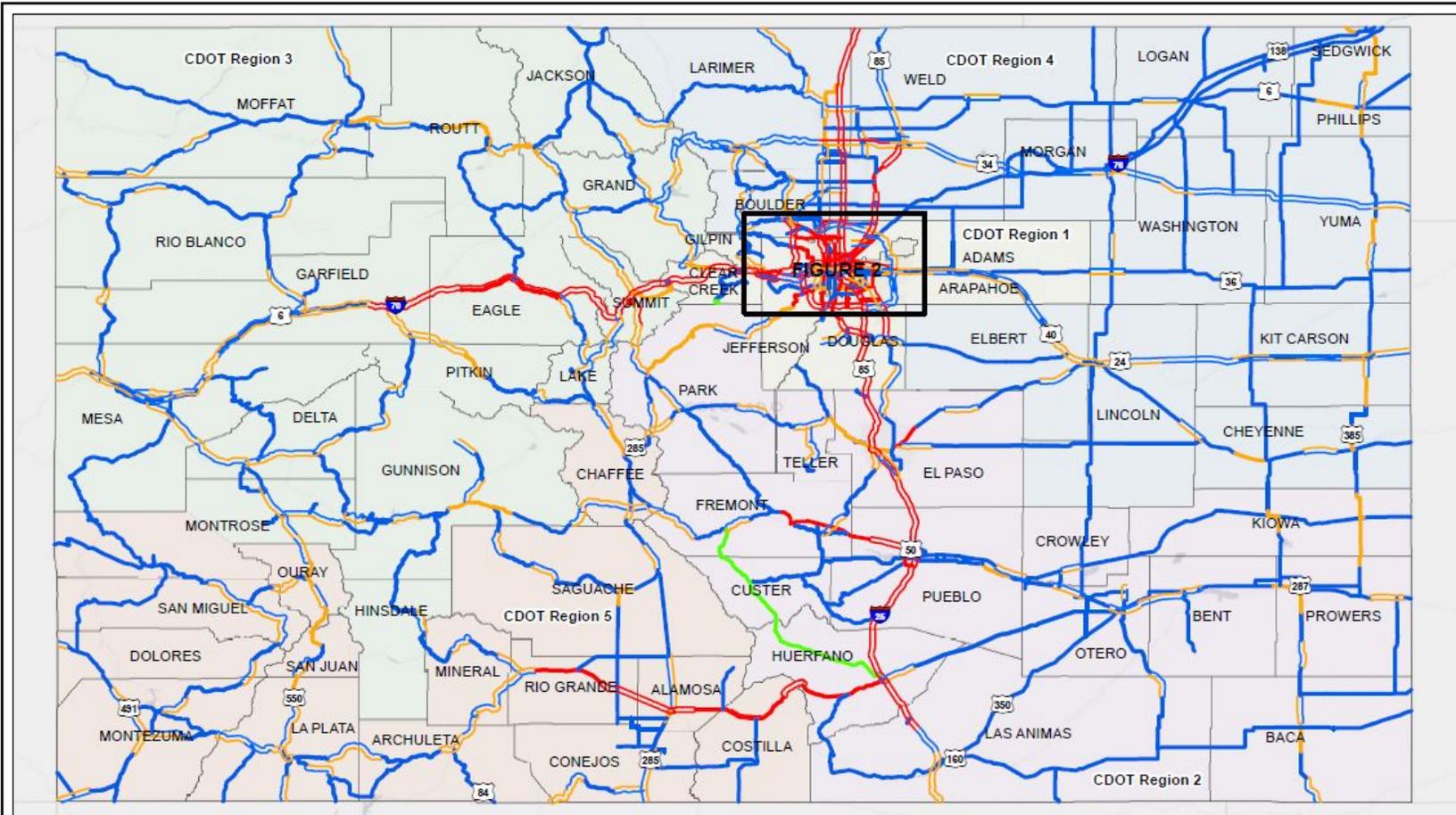
Level
6

All roadway elements designed for only vehicle level 5 systems – no signs, signals, striping... needed



Could solar roadways power our future?





Statewide (Figure 1)
Connected Road Classification System

Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community



COMMUTING



SUSTAINABILITY



TRANSPORT



SAFETY



CONNECTION

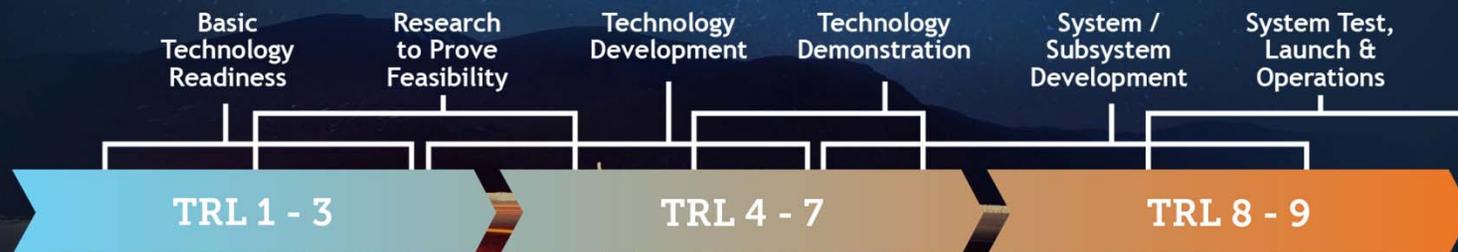


ROAD X PROJECT CLASS (RPC)

Identifying Projects Based on Technology Readiness and Risk



TECHNOLOGY READINESS LEVELS (TRL)



**TRANSPORT****TIMING : FALL 2016**

Colorado partnered with Otto of Uber to complete the world's first commercial delivery by a self-driving truck. This approximately 120-mile demonstration of self-driving technology in the real-world environment of Colorado is a monumental next step in advancing safety solutions that will help Colorado move towards zero deaths on our roadways. Colorado is enthusiastic about working with Otto and others on:



The long-term impacts and benefits of safely deploying this technology to enhance safety



Improve environmental impacts of highway freight



Foster the economic benefits advanced driving technologies are poised to bring to freight delivery and our state.

**OTTO**



CONNECTION



TIMING : Starting WINTER 2017



NHTSA Mandate for V2V

The three biggest problems facing our nation's roadways...

SAFETY



5.6 million crashes
32,719 deaths

MOBILITY



6.9 billion hours in traffic

ENVIRONMENT



3.1 billion gallons wasted

"The safety benefit of V2V is undeniable. It will save lives, and everybody knows that. A delay in rolling out V2V will cost lives, and that's a tragedy."

- Harry Lightsey, General Motors

Panasonic

V2X Deployment Program



CONNECTION



TIMING : Starting WINTER 2017



What Does V2V Unlock?

Potential...



Prevent up to **592,000** crashes

Save **1,000s** of lives

Avoid up to **270,000** injury crashes

Using This Data...



Basic Safety Message Core Data	Example Contextual Vehicle CAN Data
Latitude	Steering Wheel Angle Rate
Longitude	Brake Applied Pressure
Elevation	Throttle Position
Positional Accuracy	Wiper Set
Transmission State	Road Friction
Speed	Rain Sensor
Heading	Vehicle Mass
Steering Wheel Angle	Vehicle Type
AccelerationSet4Way	Vehicle Height
Brake System Status	AirBag Status
	Emergency Alert

To Address The Most Dangerous Crashes...

V2V technology can see where we cannot:

- Queue Warning & Crash Ahead
- Freeway Merge Assist
- Intersection Movement Assist
- Left Turn Assist
- Emergency Electronic Brake Lights
- Wrong Way Driving

V2V technology provides every vehicle with:
Real-time situational awareness for:

- Surrounding vehicles
- Weather
- Roadway conditions
- Enhanced, safer driving conditions

Panasonic

V2X Deployment Program

<http://www.nhtsa.gov/staticfiles/rulemaking/pdf/V2V/Readiness-of-V2V-Technology-for-Application-812014.pdf>



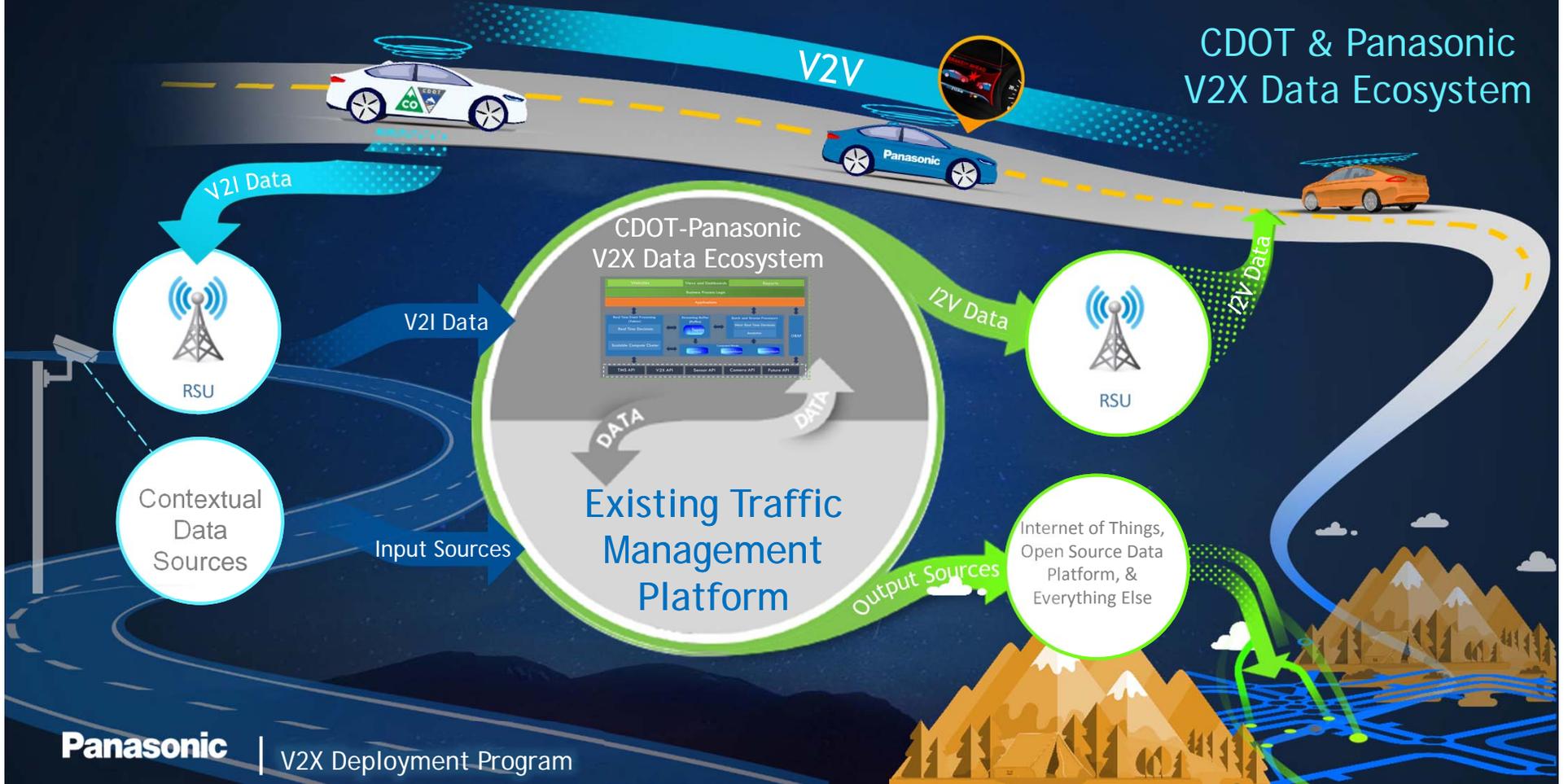
CONNECTION



TIMING : Starting WINTER 2017



CDOT & Panasonic V2X Data Ecosystem





CONNECTION



TIMING : Starting WINTER 2017



The V2X Ecosystem Unlocks More Than Just V2V

SAFETY



Prevent **419,000** additional crashes
Save **5,000** more lives
Avoid **5,000** more fatal crashes

MOBILITY



Improve freeway travel times by **42** percent
Improve arterial travel times by **27** percent
Reduce poor weather incidents by **25** percent

ENVIRONMENT



Improve fuel savings by **22** percent
Reduce VMT by **20** percent
Improve freeway travel times by **42** percent

V2X ecosystem gives roadway operators the ultimate situational awareness of all roadways, providing:

- Highly accurate, geo-located traveler information
- Highly accurate, localized weather data
- Faster emergency response times
- Improved incident management
- More intelligent, coordinated traffic signal systems
- Improved truck parking information/availability
- Enhanced maintenance decision support systems (e.g., snow plow operations)
- Improved infrastructure diagnostics (e.g., pothole identification, roadway friction)

Benefit to DOTs:

1. Empowers DOTs with data ownership and delivers open data for the world.
2. Prepares DOTs for autonomous vehicles



Panasonic

V2X Deployment Program

<https://www.its.dot.gov/factsheets/pdf/ConnectedVehicleBenefits.pdf>



CONNECTION



TIMING : Starting WINTER 2017



Critical Need for Interoperability

We have learned from traffic signal systems and enterprise tolling that interoperability is difficult to achieve as an afterthought.



V2X is built on standards. With true interoperability, roadway operators could:

- Manage roadway operations across Municipal, State, and National borders
- Coordinate freight movement of goods from urban center to freeway to parking availability to neighbor states.
- Improve operations from freeway to arterial to local roads for less congested and better traffic flow.
- Send critical, location-specific traveler information to vehicles.
- Coordinate emergency alerts, roadway conditions, and traveler information from Center-to-Center.

Panasonic

V2X Deployment Program



CONNECTION



TIMING : WINTER 2017



Smart 70 - Golden to Vail

CDOT has partnered with HERE, a leader in mapping and location technology, to create a connected vehicle environment to provide the most real-time data possible to drivers traveling through the I-70 Mountain Corridor. By using the new "RoadX" app, drivers will receive accurate travel alerts and safety warnings about potential hazards, such as traffic delays, icy conditions and crashes.

CDOT currently has a 50-person pilot testing how accurately and quickly information can be transferred using cellular networks. The ultimate goal is to eventually use the connected vehicle system to inform self-driving cars.





COMMUTING



TIMING : FALL 2017

SMART 25 - RIDGEGATE TO UNIVERSITY

Colorado will be doing a significant software and traffic sensor upgrade to the aging traffic management and ramp metering systems on the highway. This hyper-smart system will help to better manage the flow with vehicles, which could have the result of effectively adding a new lane on I-25 at a fraction of the cost.

The anticipated results are:

- More reliable trips and travel times
- Fewer crashes
- Reduction in stop-and-go traffic
- More efficient flow of traffic without expanding the roadway





SUSTAINABILITY



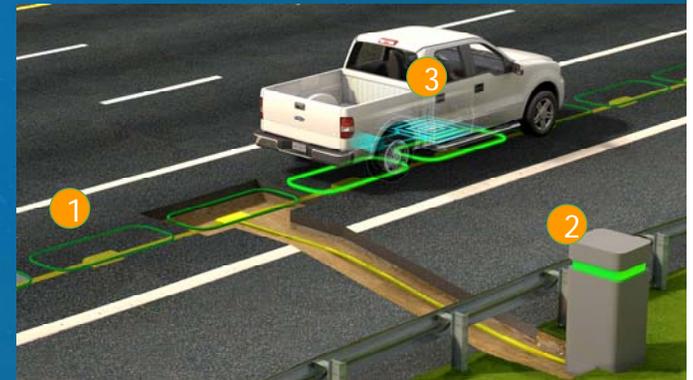
TIMING : SUMMER / Fall 2017



CDOT is looking partner with interested parties to embed power sources into Colorado's roadways that can wirelessly charge electric batteries in freight trucks while they are driving. The Smart Powered Lanes project desires to deploy this technology in live traffic for the first time in the United States. An open forum for business owners and fleet operators will be held on June 7th - join us to learn more!



- 1 Power source embedded into the roadway wirelessly transfers energy to vehicles while in motion.
- 2 Roadside equipment efficiently connects to the utility grid and distributes power to the roadway.
- 3 Minimal power storage needed within the vehicle because the batteries receive power from the roadway on the go, allowing longer trips and less battery storage.





TRANSPORT



TIMING : WINTER 2016

PHASE 1 - SMART TRUCK PARKING (PRE-PASS, CELLULAR AND DSRC)

Using detection and cloud-based software that understands and can report available parking spots to truckers, improving:

- Truckers wasted time and fuel
- Excess wear and tear on Colorado's roadways
- Excess pollution

The first phase of this project will integrate six existing parking facilities into the Smart Truck Parking System.





TRANSPORT

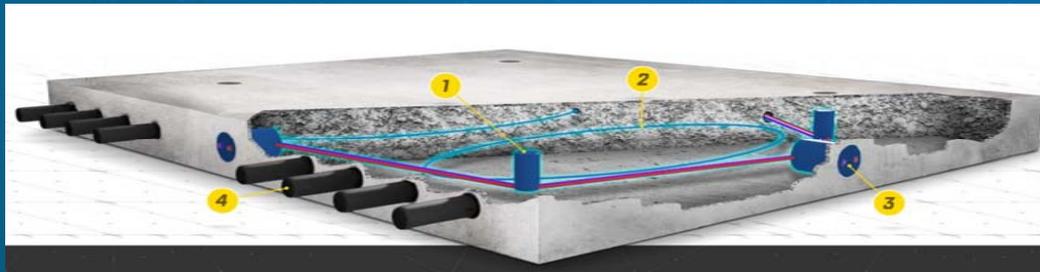


TIMING : SUMMER / FALL 2018

SMART 285 PAVEMENT

Turning existing roadways into a smart, digitally connected network that can provide weather, pavement conditions and relay possible safety concerns to the responding agencies.

- 0.8 km segment to be constructed at US 285 - Red Mountain Pass
- Immediate alerts to first responders if a vehicle leaves the roadway
- Future capabilities include inductive charging



- 1 Expansion ports for new features
- 2 Fiber Optic Sensing cable makes the road "touch sensitive"
- 3 Data and power connections at the edge
- 4 Contained within a prefab concrete slab compliant with standard pavement design specifications

2016 2017 2018 2019





TRANSPORT



TIMING : SUMMER 2017

Hyperloop is a new way to move people and freight using a custom electric motor to accelerate and decelerate levitated sleds through a low-pressure tube at speeds up to 700 mph.

- The Rocky Mountain Hyperloop team (CDOT, AECOM, Denver, Greeley and the Denver International Airport (DEN)) was selected as one of 10 worldwide winners.
- P3 between CDOT & HL1 underway to refine Initial application and define next steps
- Rocky Mountain Hyperloop Feasibility Study / Next Steps done July 1, 2018.



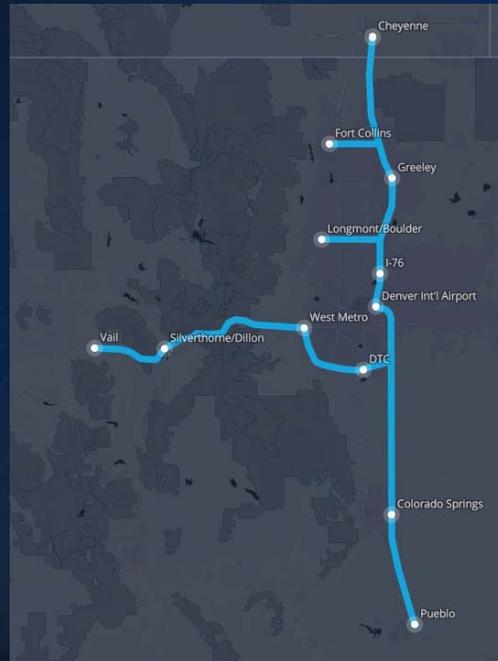
hyperloop | one



TRANSPORT



TIMING : SUMMER 2017



United States

CHEYENNE - DENVER - PUEBLO

TEAM: Rocky Mountain Hyperloop

Colorado's population growth and emerging industry sectors would benefit immensely from a Hyperloop connection along the Front Range. A high-speed link would be beneficial for the state's tourism industry, link high value-added sectors such as biotechnology, technology and aerospace, and help alleviate intercity congestion.

- Denver - Greeley: 64km, 6 min
- Denver - Fort Collins: 129km, 9 min
- Denver - Vail: 121 km, 9 min
- Denver - Colorado Springs: 118 km, 9 min
- Colorado Springs - Pueblo: 65 km, 6 min
- Total Route Length: 580 km



SUPPORTING ROADX



POLICY



PEOPLE



PLANNING

galvanize

The Learning Community For Technology

Galvanize is a dynamic learning community for technology. Their community is where people and companies with the guts and smarts to create real-world change congregate and inspire each other. Their goal is to make opportunities in technology available to all those with the aptitude, determination and drive.



The CDOT & Galvanize partnership will be mutually beneficial in three areas:

- Access to Talent

Giving CDOT access to Galvanize Experts in the areas of Data Science, Data Engineering and Full-Stack Software Engineering - to assist CDOT with any of our Project.

- Training

Galvanize will tailor training to CDOT employees, to first level set select employees in the areas of Data Science, Data Engineering and Full-Stack Software Engineering and second explore with CDOT sending employees through a Galvanize immersive program as part of the CDOT workforce of the future initiative

- Promotion of RoadX

CDOT will seek to include Galvanize in advancing RoadX initiatives and make use of Galvanize campuses that provide a unique hub of activities that bring together entrepreneurial members, large industry partners, stat-ups, students and the greater public

A MOU around this partnership was signed in Q4 of 2016

Submitted by:
Hyperloop One

AECOM
Built to deliver a better world

IN PARTNERSHIP WITH:
Colorado Department of Transportation
City and County of Denver
Denver International Airport (DEN)
City of Greeley

ROCKY MOUNTAIN HYPERLOOP

Global Challenge

October 20 16



BICYCLE & PEDESTRIAN CHALLENGE

Autonomous Mobility Policy White Paper
Colorado Department of Transportation
Colorado Department of Revenue
Colorado Department of Safety

DRAFT 08/2016



NEXT STEPS



People
Educate public



ROI
Invest now in
technology platforms



Privacy
Address security
issues



Technology & Planning
Plan and model
for rapid change



Regulation
Establish consistent policy
direction that supports
autonomous future

QUESTIONS?

