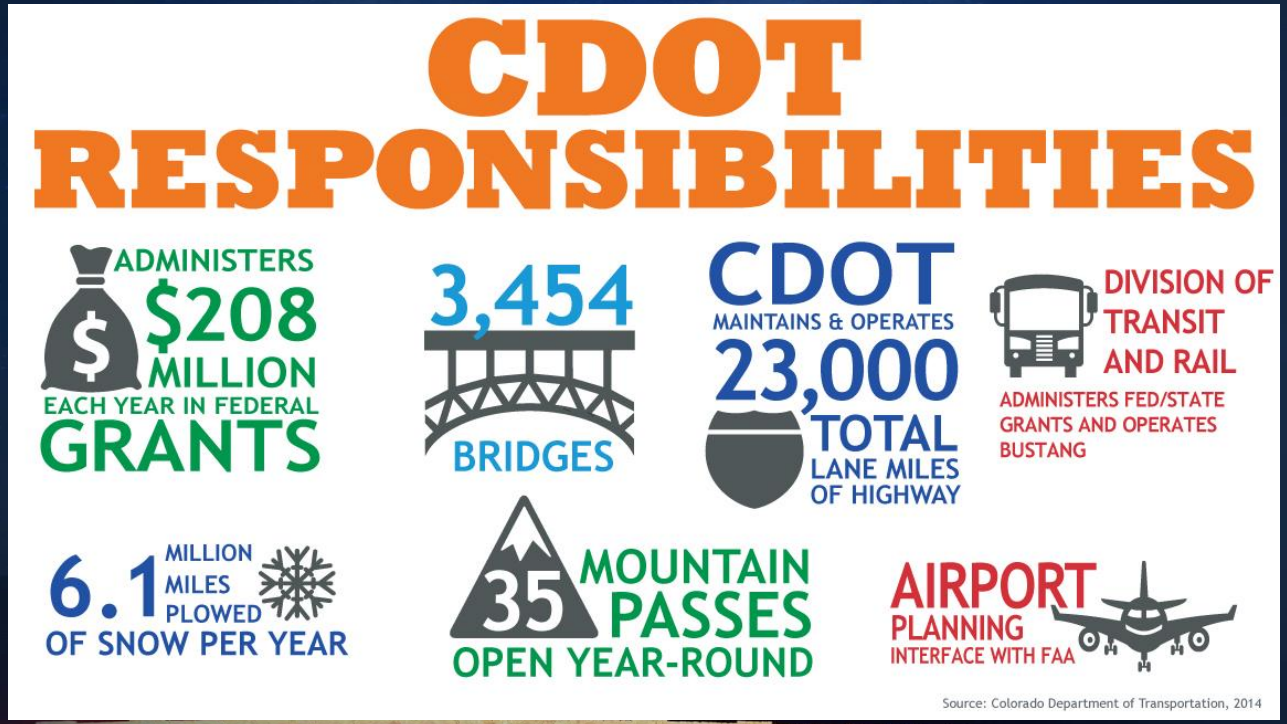
Town of Vail – Future of Mobility
RoadX Overview
September 4, 2018

FY 2016-2017 $1.44 Billion Budget



OUR CHALLENGE : CONTINUED GROWTH

ROADX
ACCELERATING TECHNOLOGY

1991

3.3 million

27.7 billion
vehicles miles traveled

$$$$$$$$$$$$$$$$
$$$$$$$$$$$$$$$$
$$$$$$$$$$$$$$$$
$$$$$$$$$$$$$$$

$125.70
spent per person

2015

5.4 million

50.5 billion
vehicle miles traveled

$$$$$$$$$$$$$$$$
$$$$$$$$$$$$$$$$
$$

$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 ARE WE LOOKING TO TECHNOLOGY?

SAFETY

80% reduction in crashes per NHTSA estimates

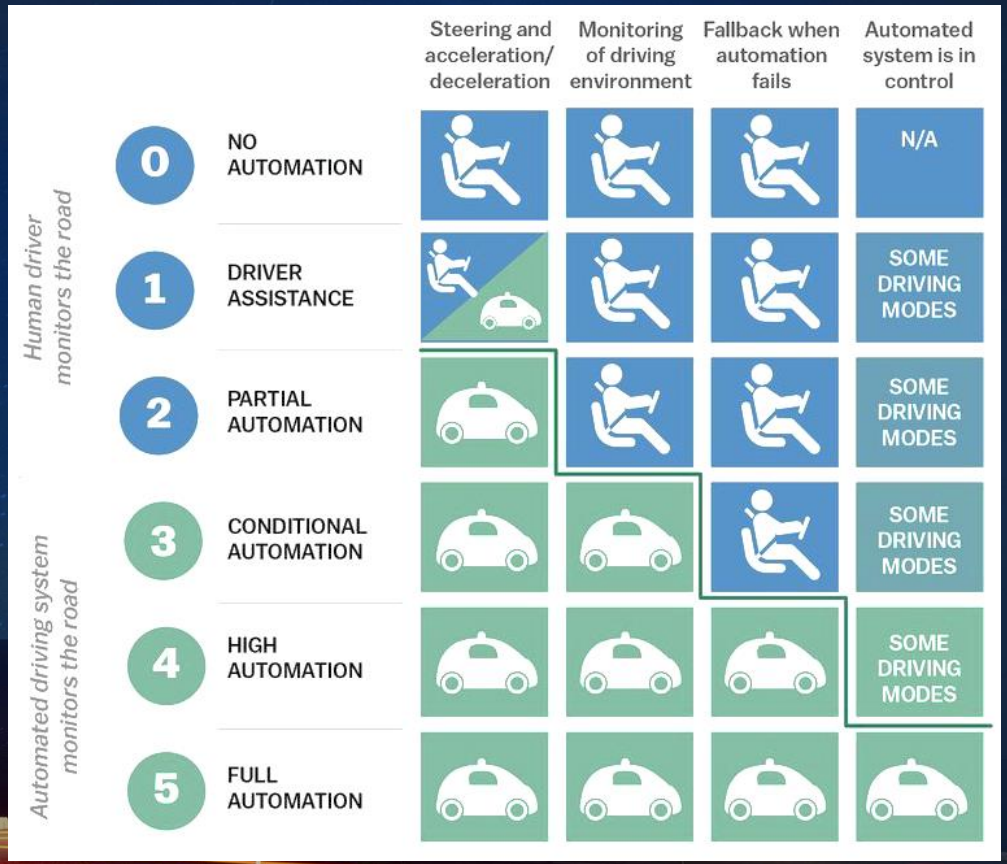
MOBILITY

40 to 400% increase in capacity

5 LEVELS OF DRIVING AUTOMATION

Human driver

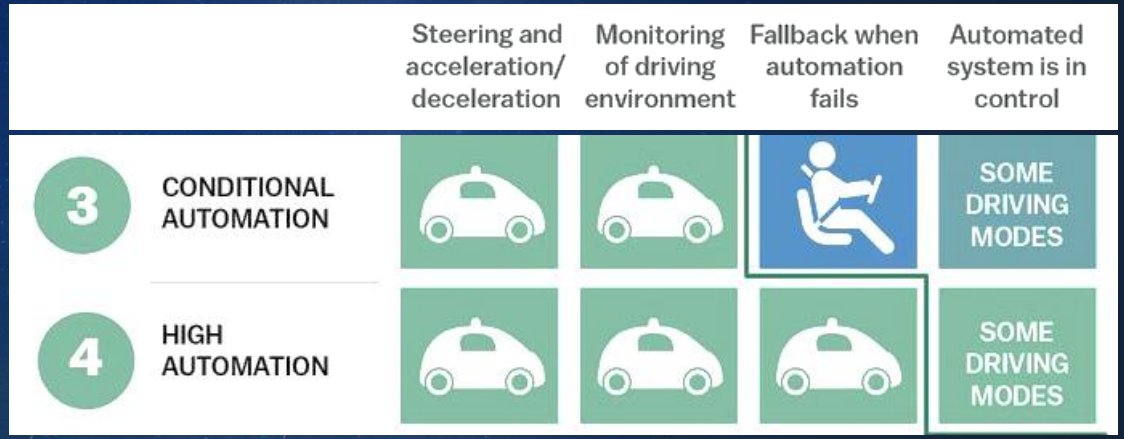
Automated system



Highly Automated Vehicles (HAVs)

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.



CONNECTED ROAD CLASSIFICATION SYSTEM

Level 1

Unpaved and/or non-striped 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 date 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

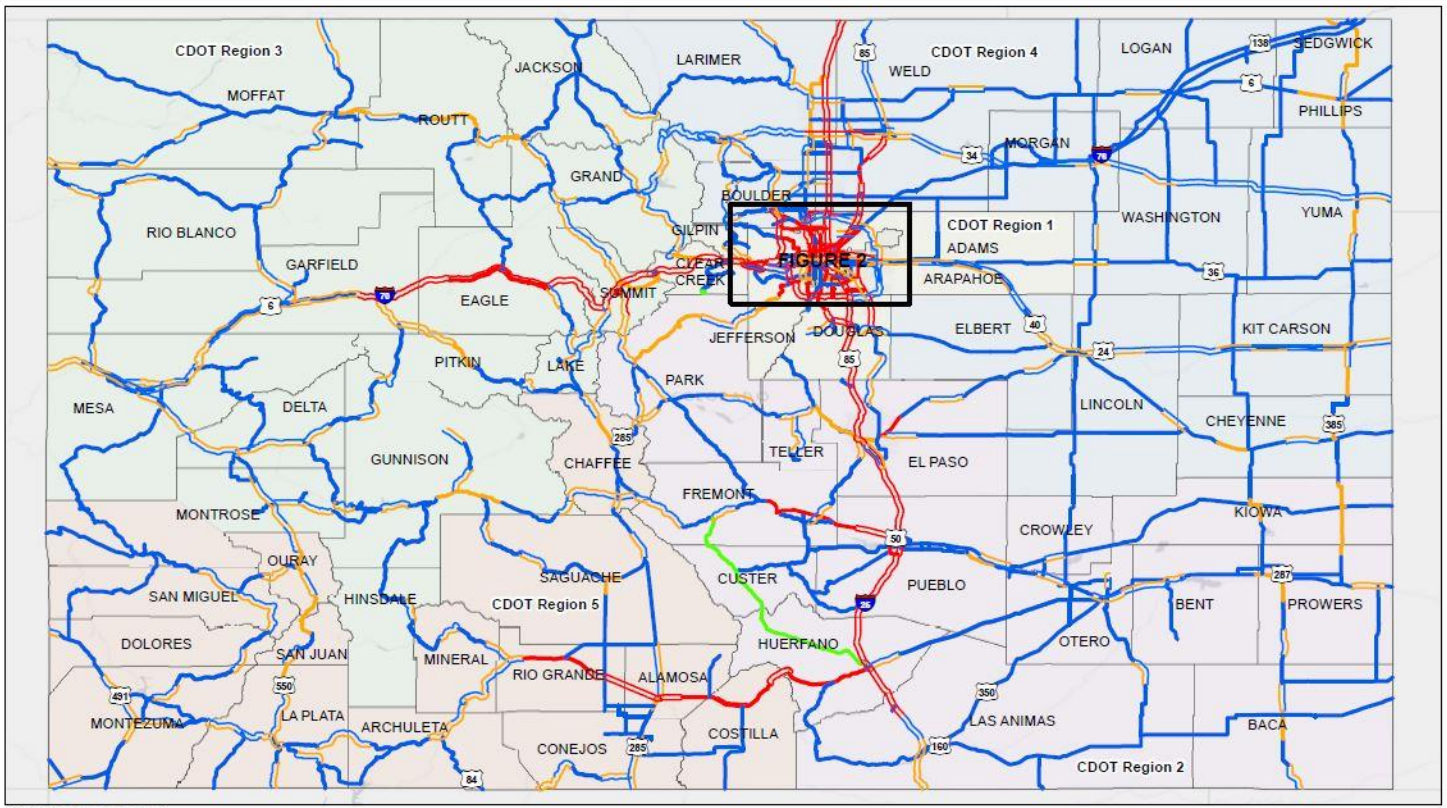
Roadway or specific lane(s) has adaptive ITS equipment (i.e. smart signals hold for vehicles, highway lighting that turn on for vehicles, etc.) with Traffic Operations Center override only, and/or two way data share between DOT/Vehicle/User, and/or lanes designated for vehicle levels 3 & 4 only

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


CDOT Region 3
MOFFAT
ROUTT
JACKSON
LARIMER
CDOT Region 4
WELD
LOGAN
SEDGWICK
PHILLIPS
MORGAN
GRAND
BOULDER
GILPIN
CDOT Region 1
ADAMS
ARAPAHOE
WASHINGTON
YUMA
RIO BLANCO
GARFIELD
EAGLE
SUMMIT
CLEAR CREEK
FIGURE 2
JEFFERSON
DOUGLAS
ELBERT
KIT CARSON
PITKIN
LAKE
PARK
MESA
DELTA
LINCOLN
CHEYENNE
GUNNISON
CHAFFEE
TELLER
EL PASO
FREMONT
MONTROSE
CROWLEY
KIOWA
OURAY
SAGUACHE
CUSTER
PUEBLO
SAN MIGUEL
HINSDALE
CDOT Region 5
BENT
PROWERS
DOLORES
SAN JUAN
MINERAL
HUERFANO
OTERO
RIO GRANDE
ALAMOSA
MONTEZUMA
LA PLATA
ARCHULETA
CONEJOS
COSTILLA
LAS ANIMAS
BACA
CDOT Region 2
Roadway Classification
Level 1
Level 2
Level 3
Level 4
0
25
50
100
Miles
N
Statewide (Figure 1)
Connected Road Classification System
Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

CONNECTION | TIMING : STARTING WINTER 2017

ROADX ACCELERATING TECHNOLOGY

THREE BIGGEST PROBLEMS WE FACE…

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


CONNECTION
TIMING : STARTING WINTER 2017
ROADX
ACCELERATING TECHNOLOGY
CDOT AND PANASONIC
V2X DATA ECOSYSTEM
V2V
Panasonic
V2I Data
RSU
V2I Data
CDOT-Panasonic
V2X Data Ecosystem
I2V Data
RSU
I2V Data
DATA
DATA
Contextual
Data
Sources
Input Sources
Existing Traffic
Management
Platform
Output Sources
Internet of Things,
Open Source Data
Platform, &
Everything Else

ROADX ACCELERATING TECHNOLOGY

SMART 70

Pilot Deployment

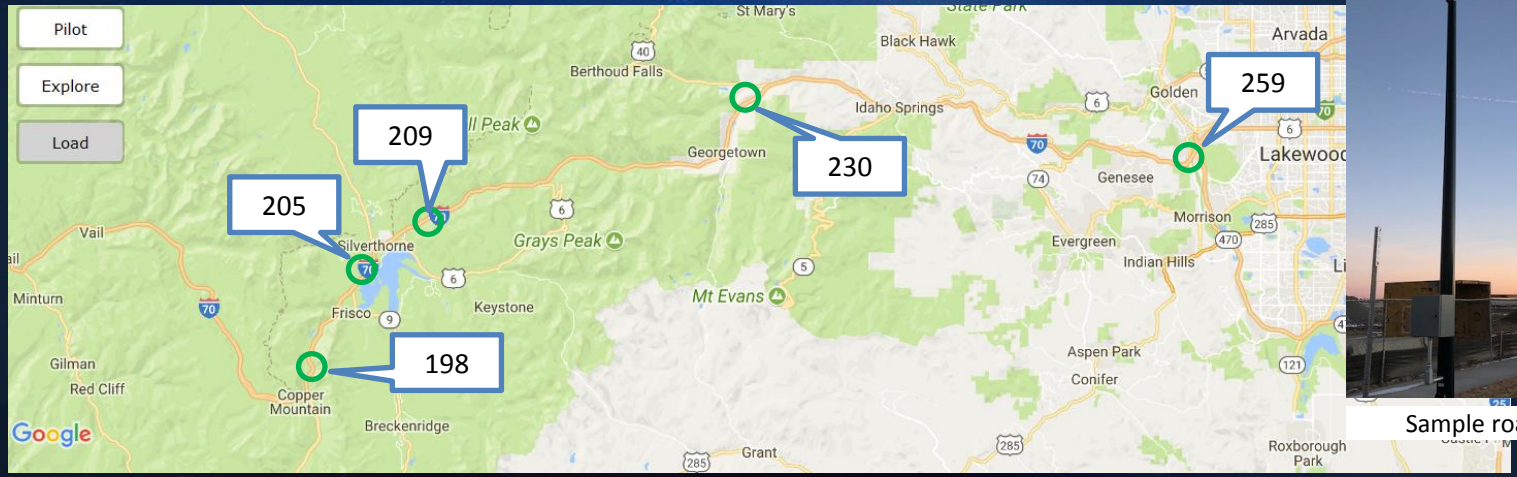
CDOT & Panasonic are beginning the field deployment and testing phase of the V2X Deployment Program. The initial pilot deployment includes:

- Installing 5 pilot roadside units (RSUs)
- Outfitting select CDOT test vehicles with on-board units (OBUs)
- Establishing field communications
- Beginning initial testing
- Educating the team prior to full corridor deployment
- Learning lessons to apply to future project installations as the team moves into the full 90-mile deployment

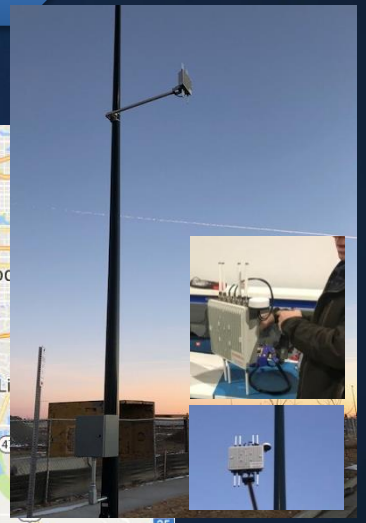
CDOT | ROADX
ACCELERATING TECHNOLOGY

SMART 70

Phase 0	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Program Planning	Vehicle-to-Infrastructure	Infrastructure-to-Vehicle	Vehicle-to-Vehicle	Enhanced Data Analytics	End-to-End Deployment



Preliminary pilot site locations



Sample roadside unit

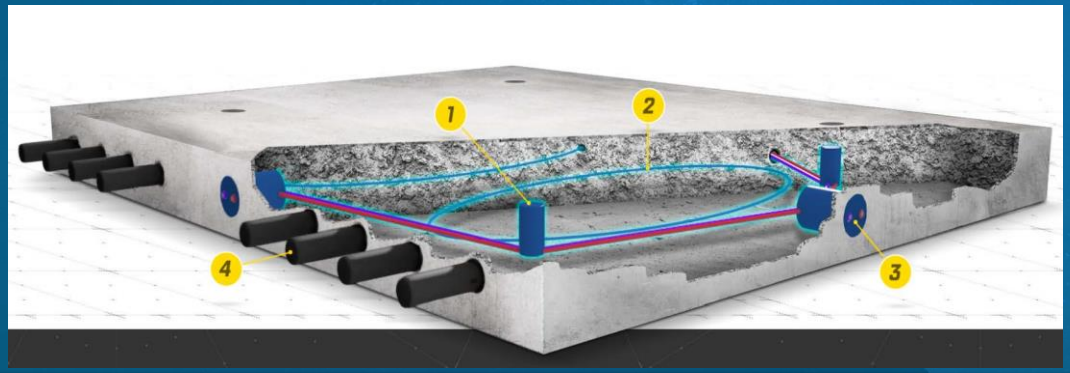
TRANSPORT | TIMING : SUMMER / FALL 2018

ROADX ACCELERATING TECHNOLOGY

SMART 285 PAVEMENT

Turning existing roadways into a smart, digitally connected network that and 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 Hill 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

ROADX ACCELERATING TECHNOLOGY

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.

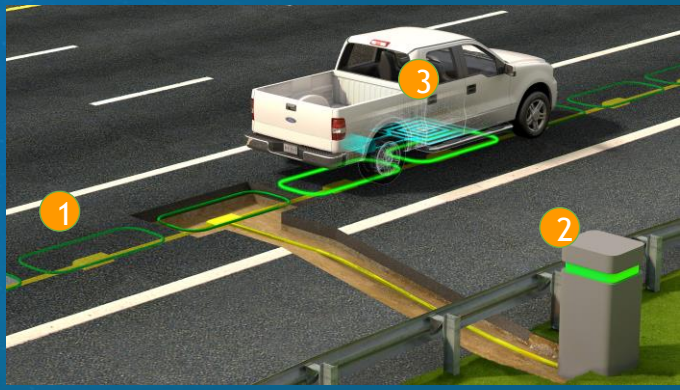
SUSTAINABILITY | TIMING : SUMMER / FALL 2017

ROADX ACCELERATING TECHNOLOGY

SMART POWERED LANES

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 7 – 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.



2016 2017 2018 2019

ROADX ACCELERATING TECHNOLOGY

HYPERLOOP

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.

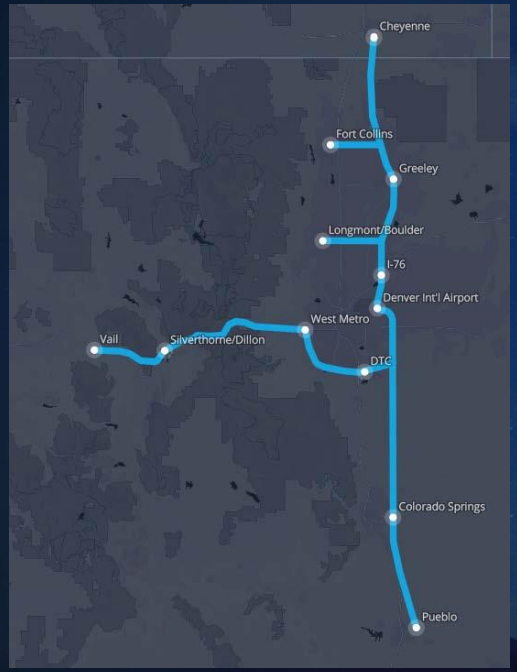
- The Rocky Mountain Hyperloop team (CDOT, AECOM, Denver, Greeley and the Denver International Airport (DEN)) was selected as one of 10 worldwide winners.
- P3 between CDOT & HL1 underway to refine Initial application and define next steps
- Rocky Mountain Hyperloop Feasibility Study / Next Steps done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

2016 2017 2018 2019

hyperloop | one

TRANSPORT | TIMING : SUMMER 2017

ROADX ACCELERATING TECHNOLOGY



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

2016 2017 2018 2019

hyperloop one

The Players

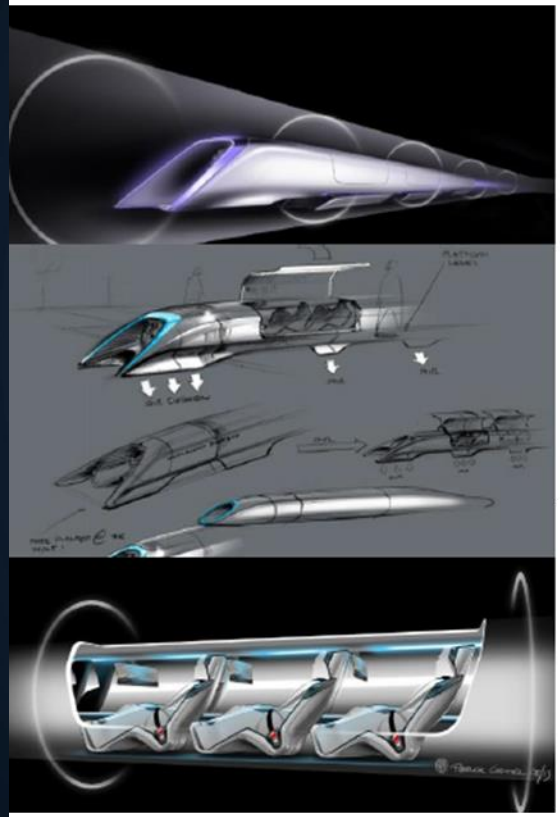
HYPERLOOP TRANSPORTATION TECHNOLOGIES

- Crowd-funded company trying to commercialize for human transport
- Building a 5-mile prototype in Central California
- Signed a deal for feasibility study in Slovakia

HYPERLOOP

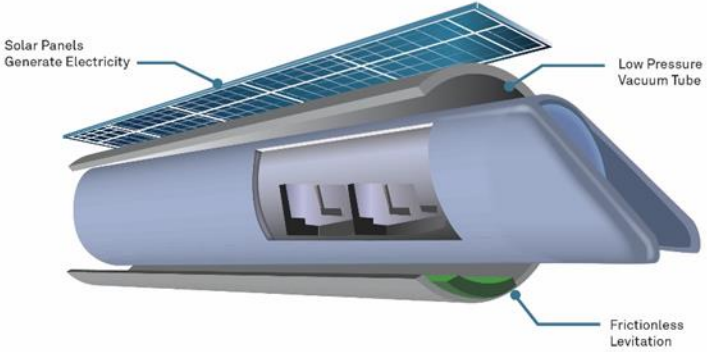
- Venture backed ($100M+) startup in Los Angeles, CA
- Building a test track in North Las Vegas
- Conducting feasibility studies for freight and passenger
- Global Challenge to identify new studies

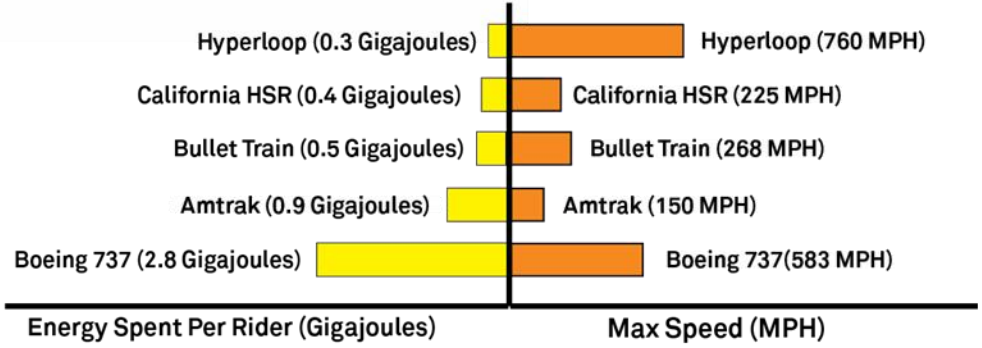
SpaceX



"It's a cross between a Concorde, a rail gun, and an air hockey table."

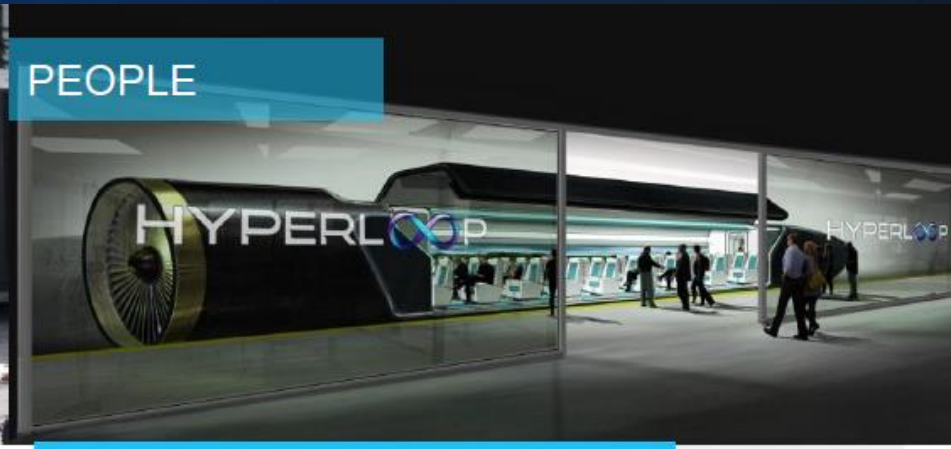
ELON MUSK





Moves Anything

- Transports 1 or 2 FEU (forty foot equivalent unit)
- Ship a pod every 10 seconds
- Provides cost-effective and fast method of shipping time sensitive goods
- Travels faster than passengers due to allowable g-loading



- A tube/pod system designed for cargo can also carry people
- Includes more stringent safety and escape measures
- Pods have ECLS (Environmental Controls & Life Support) System

Goes Anywhere

- Removes need for grading
- Easily crosses natural barriers
  - Bridges are cheaper due to low mass per pod
  - Tunnels are cheaper due to tube's resistance to external pressure
- Does not restrict access or R.O.W.
- Reaches city centers above grade or via tunnel

- Eliminates R.O.W. issues
- Enables offshore ports which can deliver goods to inland ports via minor tunneling
- Reallocates waterfront property

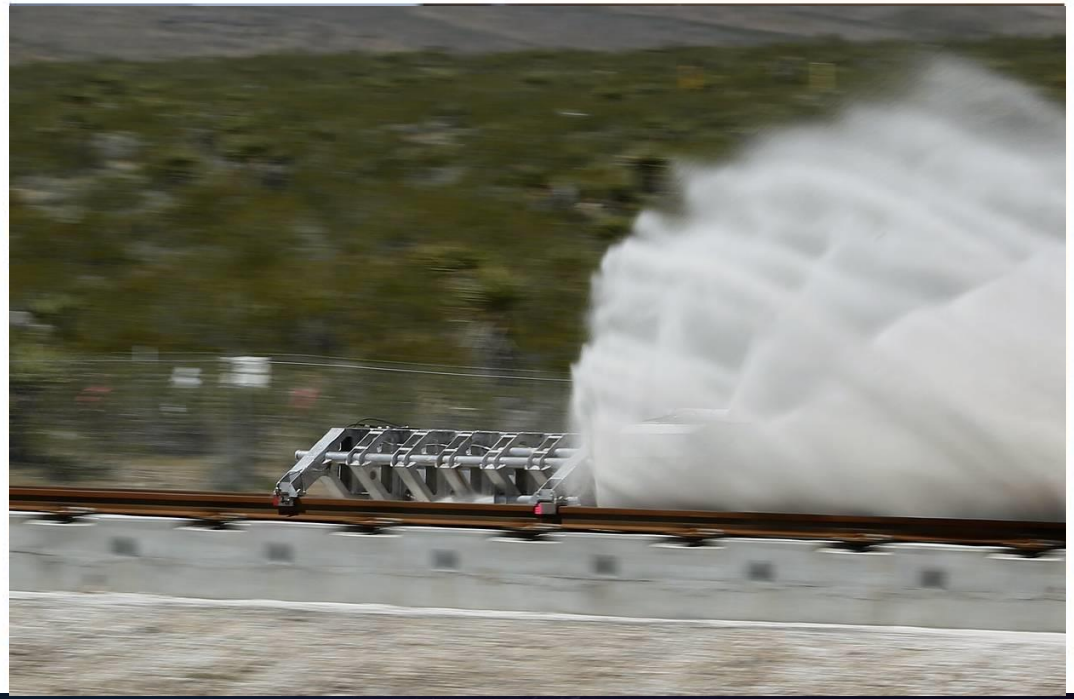
Changes the Future

- ENABLES an on-demand economy
- TRANSFORMS cities
- RESHAPES shipping and logistics industries
- UNLOCKS real estate value
- PROFOUNDLY IMPACTS human behavior and our interaction with the Earth
- REDUCES pollution

The fastest, cleanest, safest way to connect the world.

	BOAT	TRAIN	TRUCK	AIRPLANE	HYPERLOOP
Cost Effective	●	●	◖		●
High Speed		◖		●	●
Ultra Safe	●	◖		◖	●
Weatherproof					●
Energy Efficient	●	●			●
Carbon Free		◖			●
On-Demand			●		●
Unrestrictive of ROW	●			●	●
Driverless					●

Propulsion Open Air Test



Propulsion Validation

0-540 km/h in 2 sec in Q1-2 2016

- Custom linear electric motor designed for full speed operation at 300 m/s
- Power electronics and supporting medium voltage power & signal conditioning components
- Validates fully automated controls

ROADX ACCELERATING TECHNOLOGY

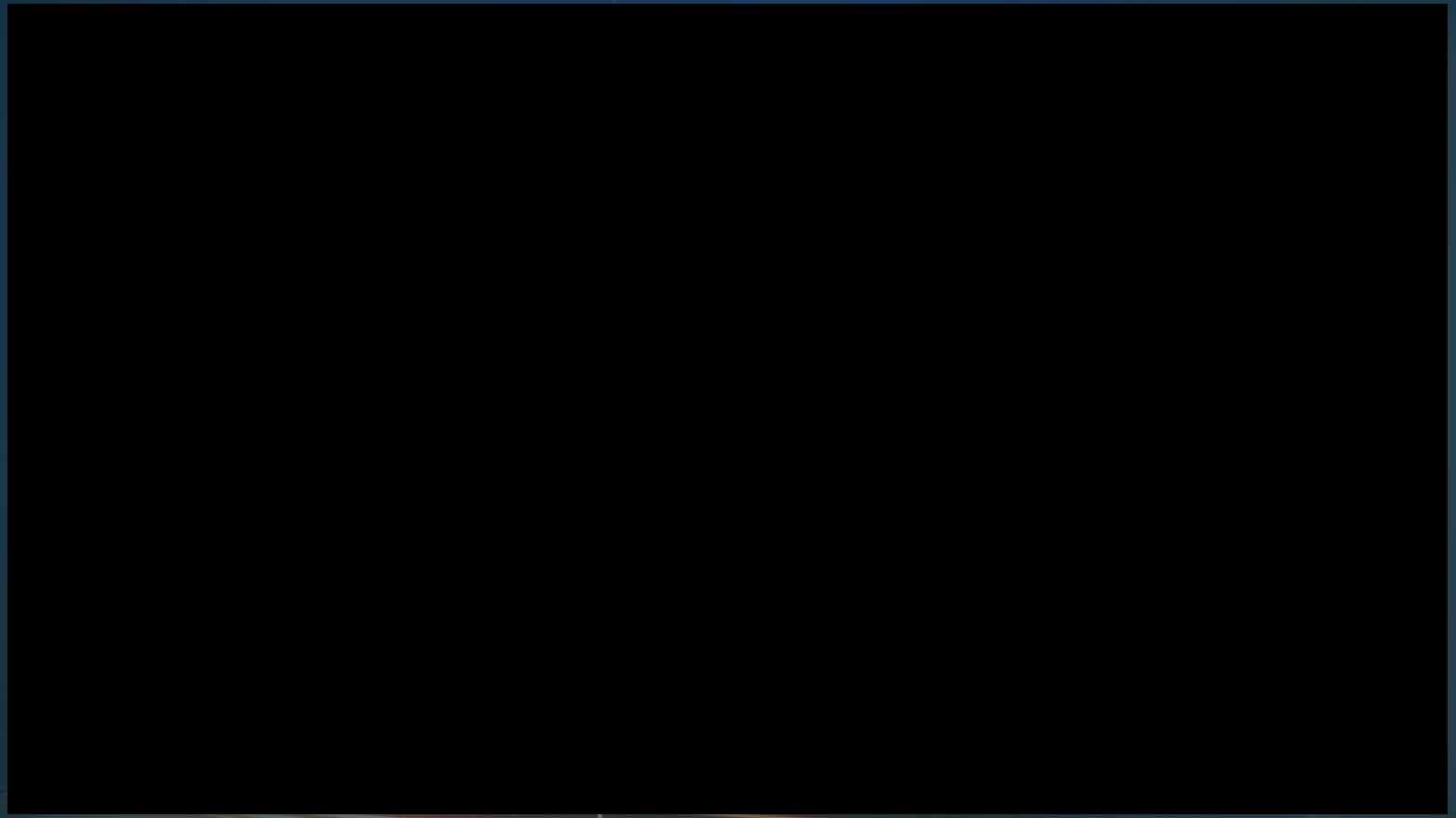
ARRIVO

Arrivo is a new take on a regional transportation system that aims to be safe, fast and clean. The Arrivo system propels four models of vehicles through an enclosed, electromagnetic superhighway, using magnetic levitation to float the vehicles and an all-electric linear motor to push them forward at speeds up to 200 mph with zero emissions.

ARRIVO'S INVOLVEMENT IN COLORADO INCLUDES:

- Development of a full system test track adjacent to E-470
- The creation of 200+ jobs in the Denver metro area by 2020 along with a Arrivo Engineering and Technology Center
- Arrival at DEN in under 20 minutes from anywhere in the Denver metro area

2016 2017 2018 2019



CDOT | ROADX
ACCELERATING TECHNOLOGY

ROADX ACCELERATING TECHNOLOGY

RAPID SPEED STUDY

State Rapid Speed Benefits and Opportunities Study

Funded by the state and shared during development with technologists.
Will address, among other issues:

- Which agency will oversee and regulate this new technology?
- What governance structure will apply?
- Which environmental approval processes will be applied?
- Determine what CDOT's and private partner's role in ownership, construction, operations, maintenance, and funding will be?
- While individual technologists may define specific beginning routes, how will this impact larger network and land use?

ROADX ACCELERATING TECHNOLOGY

RAPID SPEED STUDY

Technologists Feasibility Analysis

Funded by technologist and shared during development with the State Benefits and Opportunities Study. Will include:

- Technology assessment
- Routes and market assessment
- Operations Plan

SAFETY | TIMING : SUMMER 2017

Autonomous Impact Protection Vehicle (AIPV)

To save lives, CDOT uses impact protection vehicles that act as a barrier to protect employees working on or near active roadways.

In August, CDOT and partners at Colas UK, Royal Truck & Equipment, and Kratos Defense placed in service a first-of-its kind Autonomous Impact Protection Vehicle (AIPV). By using self-driving technology, CDOT is able to take the driver out of harm's way while still effectively shielding roadside workers.

2016 2017 2018 2019

CDOT CO | ROADX
ACCELERATING TECHNOLOGY

NEXT STEPS

Privacy
Address security issues

People
Educate public

Technology & Planning
Plan and model for rapid change

ROI
Invest now in technology platforms

Regulation
Establish consistent policy direction that supports autonomous future

PREPARING THE VAIL VALLEY

- Define your objectives (use cases, applications,…)
- Identify your ODD
- Innovatory existing assets
- Tier deployment strategies & investments
- Incorporate objectives / ODD into land use and planning
- Deploy…

QUESTIONS?