



THE INTERNET OF ROADWAYS

Colorado's vision, strategy, and approach to building the United States' first connected vehicle network



PRESENTATION SUMMARY

Intelligent Transportation Systems at CDOT (overview)

Smart Mobility Planning

Fiber Planning

Building Colorado's Internet of Roads (Connected Vehicle (V2X) Network)

Discussion



INTELLIGENT TRANSPORTATION IN COLORADO

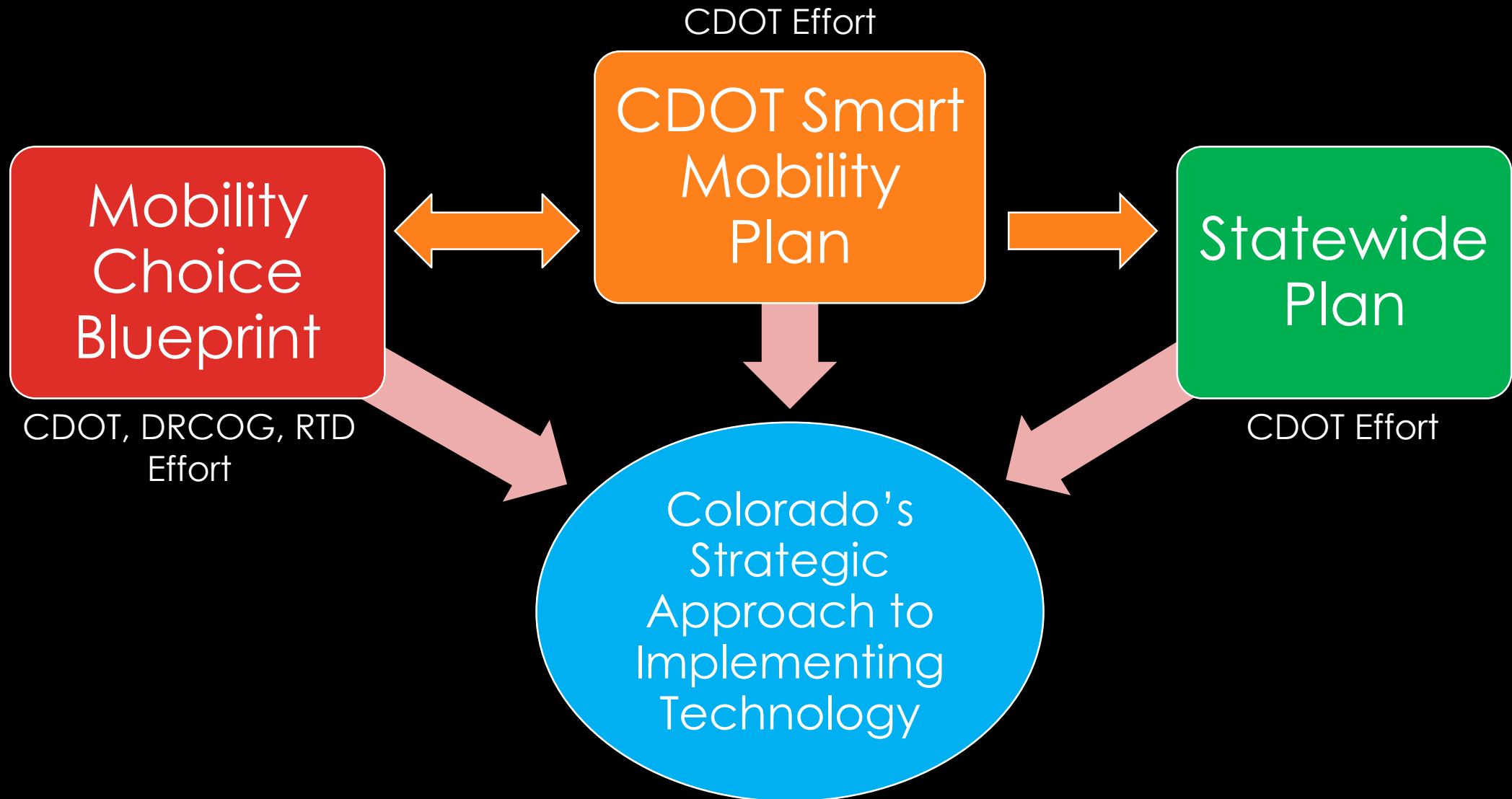
CDOT's Intelligent Transportation Systems (ITS) branch exists to improve the safety and efficiency of Colorado's transportation system through advanced technology deployment.

Principally, CDOT ITS seeks to realize a connected and autonomous mobility future in Colorado through three main pillars:

- Innovation**
- Infrastructure**
- Information System**



ACTIVE TECHNOLOGY PLANNING EFFORTS





PLANNING FOR SMART MOBILITY

Smart Mobility Plan

Unified Approach for Advancing
Intelligent Transportation

Existing & Future Technologies

Steps toward Autonomous &
Future Mobility

Internet of Roads
(Connected Vehicle Network)

Near-term
Technology Revolution

Fiber Master Planning

Principal Foundation for
Intelligent Transportation



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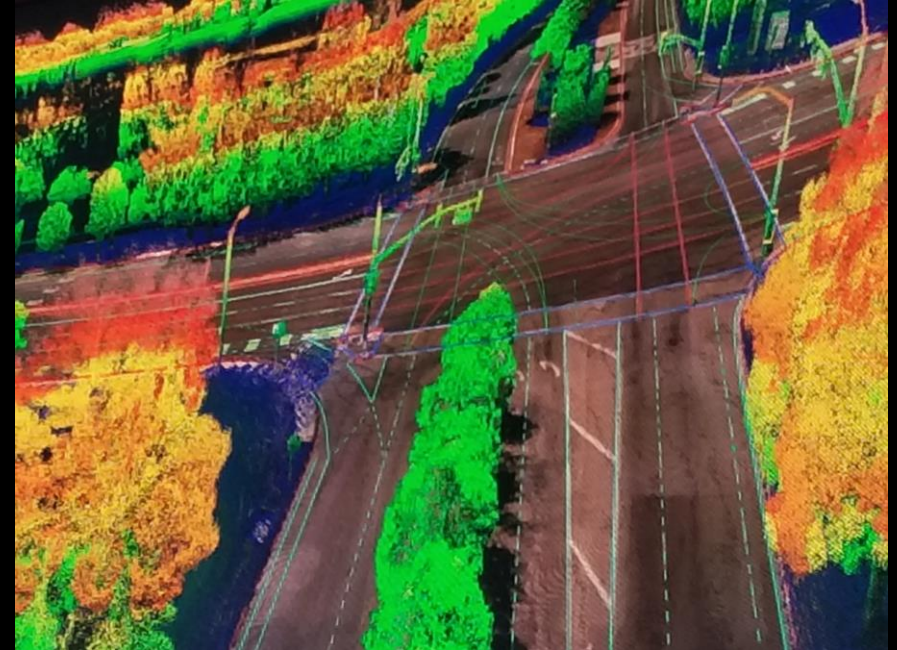




PLANNING FOR SMART MOBILITY

CDOT's Smart Mobility Plan will...

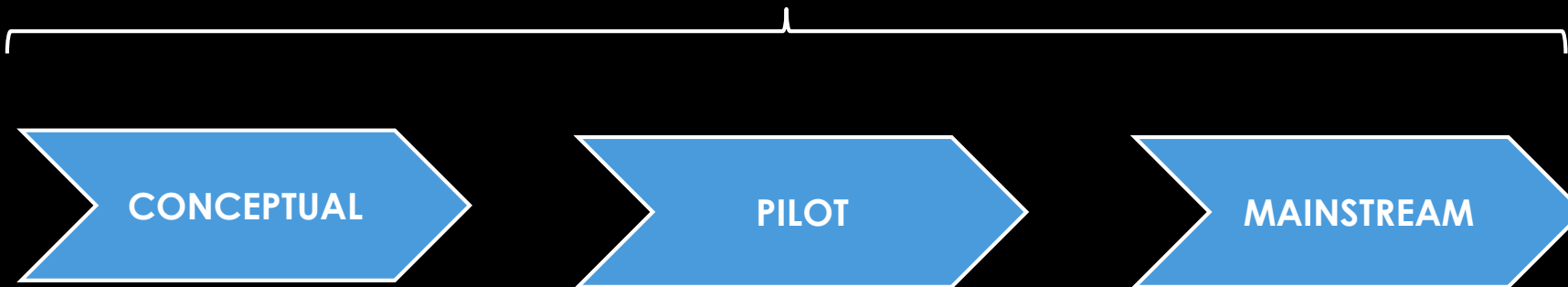
- Create a 5 to 10 year vision and plan for maximizing the benefits of new technologies in the transportation sector.
- Define goals to improve safety and efficiency of Colorado's transportation system through the use of technology.
- Prepare CDOT's assets, data management, communications systems and infrastructure to maximize the benefits of connected and autonomous vehicles.





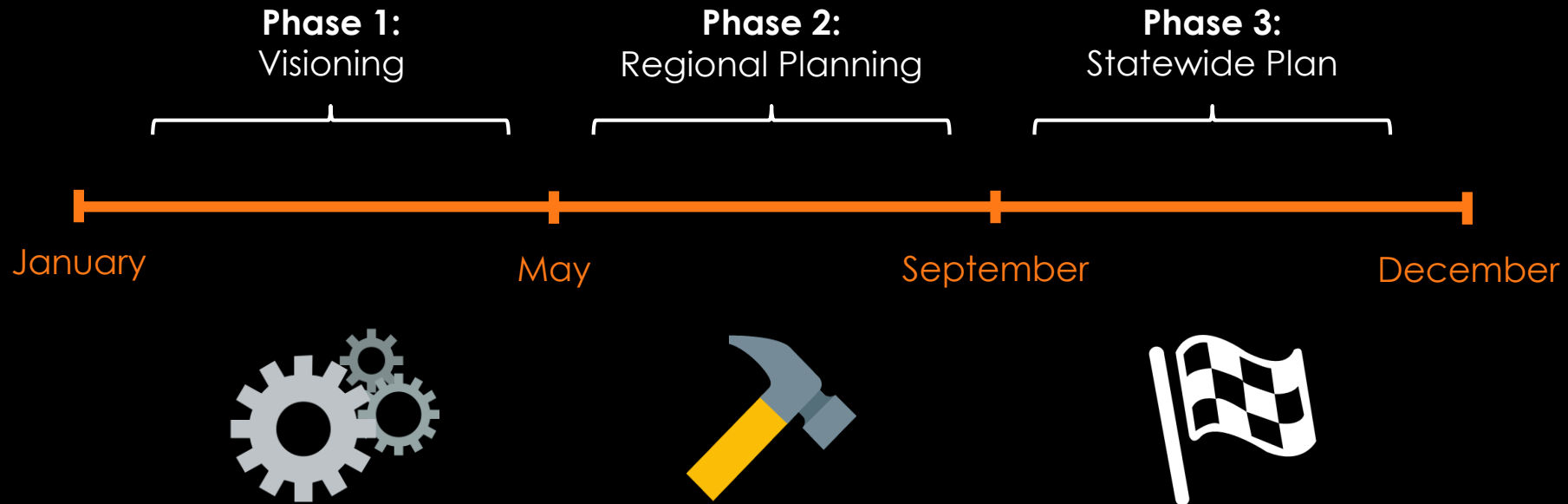
PLANNING FOR SMART MOBILITY

The Technology Toolbox will Provide a Pipeline for Accelerating Innovation





PLANNING FOR SMART MOBILITY





PLANNING FOR SMART MOBILITY

Smart Technology Future
for Colorado

- Transparent, articulate and integrated approach to cutting edge technology deployment in Colorado

Budgetary &
Institutional Support

- Continued State and Federal support
- Line items for technology projects
- Other cost shares where appropriate

Link to Other
Transportation Planning Efforts

- Broad-spanning partnerships to align larger statewide plan with other relevant planning efforts

Colorado Smart Mobility Plan

- 5 to 10 year summary plan for statewide technology deployment + tech toolbox
- Dynamic technology committee

Regional Technology Plans

- Foundation to build unified support and planning for innovative local & regional technology projects



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FIBER PLANNING & DEVELOPMENT

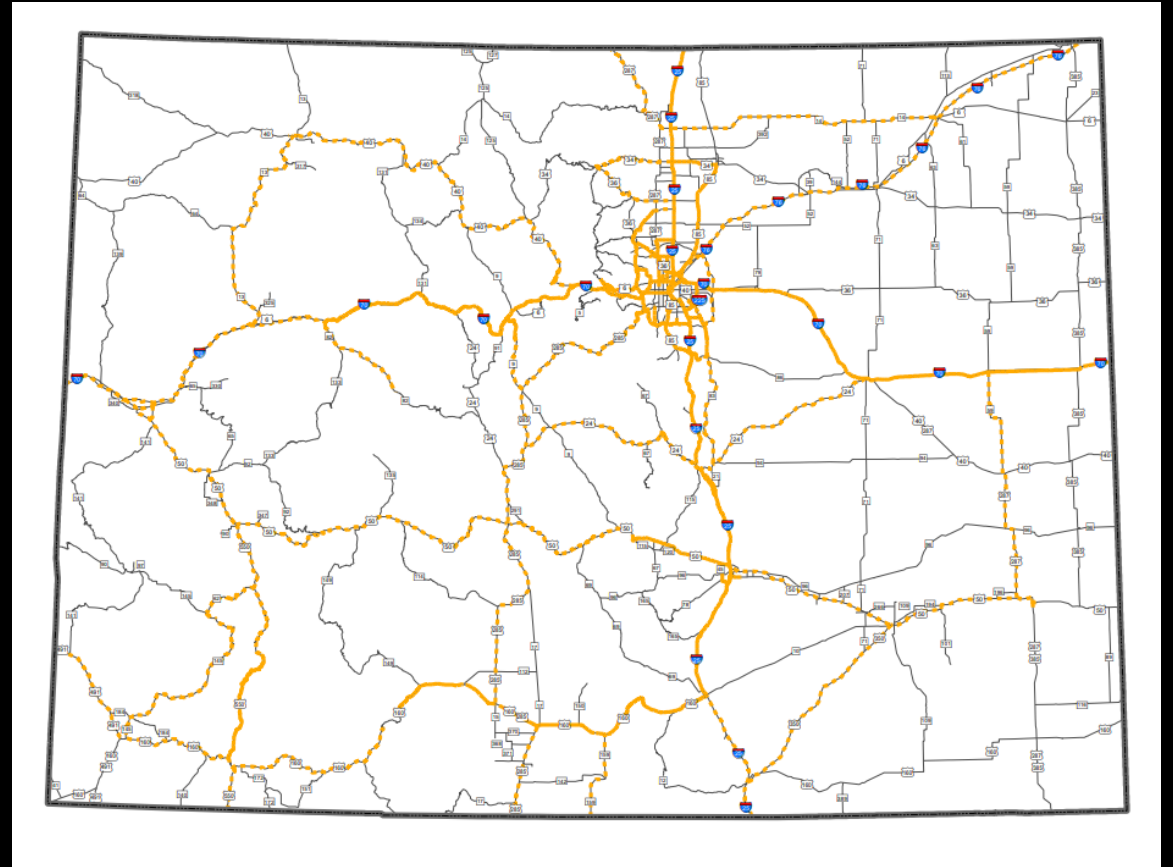




FIBER PLANNING & DEVELOPMENT

Fiber Planning, the foundation...

- Develop a 5-10 year fiber and network strategy to support the future transportation network with connected and autonomous vehicles.
- Identify routes based on a weighted factors, which include CDOT Region input, economic development and public safety needs.
- Building blocks to the Smart Mobility Plan.





FIBER PLANNING & DEVELOPMENT

Building Partnerships to expand CDOT's fiber footprint...

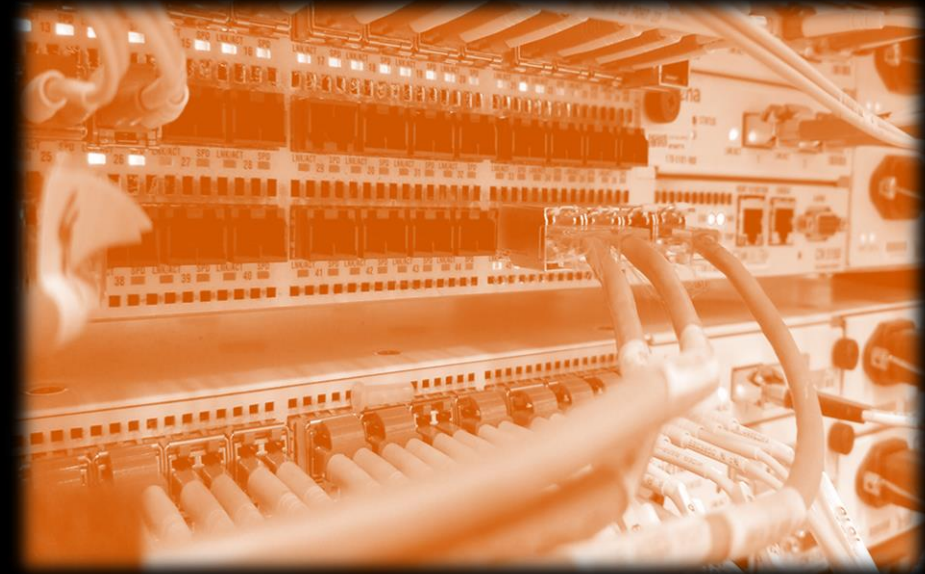
- Opportunities to partner with Public and Private organizations come to CDOT in many forms.
- Once an opportunity is identified, the entity submits a Unsolicited Proposal to ITS Planning.
- ITS Planning, who chairs Fiber Management Team (FMT) will present the opportunity to the FMT to review and approve.
- Once the terms and conditions are ironed out, ITS Planning submit to the appropriate State and CDOT Departments for finalization.



FIBER PLANNING & DEVELOPMENT

P3s, why are these partnerships important...

- Create an environment that fosters **communications & technology** advancement for **ALL** of Colorado
- Improve community and State **resiliency**
- Promote **economic development**
- Grow an **interoperable** and **consistent** transportation network system
- To **expand information networks** while leveraging the existing transportation “hard” infrastructure
- **Collecting data** to create **thoughtful, informed decisions** to improve our transportation network, while **enhancing technology abilities locally**





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BLANK SLATE

CDOT is building a new digital infrastructure from scratch

Transportation systems are becoming information systems

Roadways will be influenced by digital messages, not just physical infrastructure

Need to maintain our ability to influence and improve roadway conditions

Build where the problems are

Deploy holistic network, not piecemeal







CDOT AND PANASONIC

Panasonic = CV Foundation

iOS platform

C-V2X, DSRC neutral

Open, interoperable

How do we build a meaningful CV network at a scale that begins solving problems?



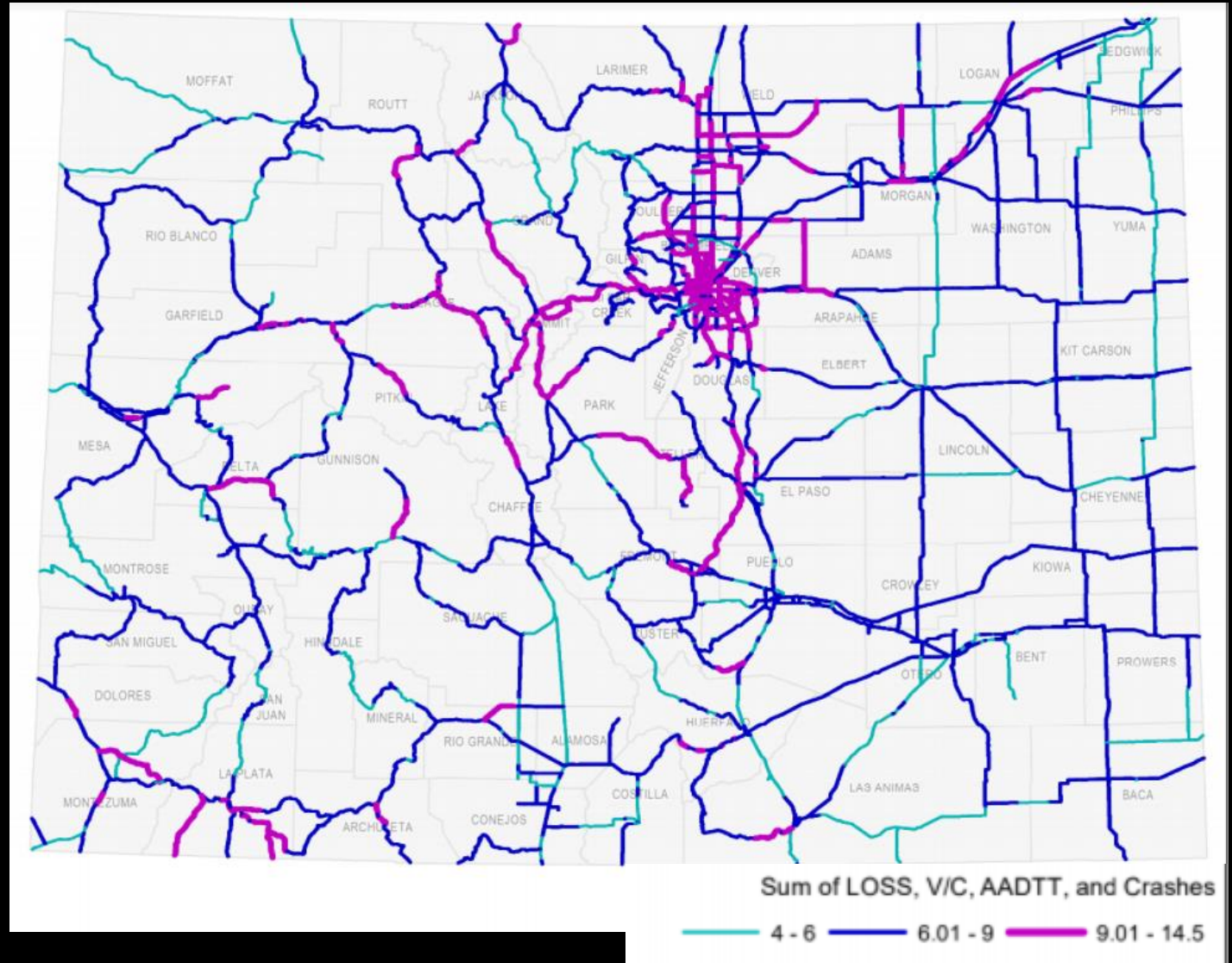


FACTORS OF CONSIDERATION

Safety

Mobility

Freight





SAFETY BENEFIT ANALYSIS

First-ever methodology created by CDOT Traffic Safety

Conservative Assumptions:

- CV App = CMF safety benefit
- CV Apps are customized, relevant, just-in-time
- Only three CV apps shown = hundreds possible
- Market penetrations of 5-10%
- Does not consider benefits operational V2I improvements
- Handful of corridors

Quantifying the safety benefits of connected vehicles

CV Application	CMF Equivalent	Reduction % (PDO, Injury, Fatality)
Spot Weather Warning	Variable Message Signs (VMS)	25%
Roadway Departure Warning	Rumble Strips	11%-16%
Queue Warning	Queue Ahead Warning	16%
Dynamic Speed Harmonization	Variable Speed Limits (VSL)	19%



SAFETY BENEFIT ANALYSIS

Quantifying the safety benefits of connected vehicles

EXAMPLE: I-25 in Region 1

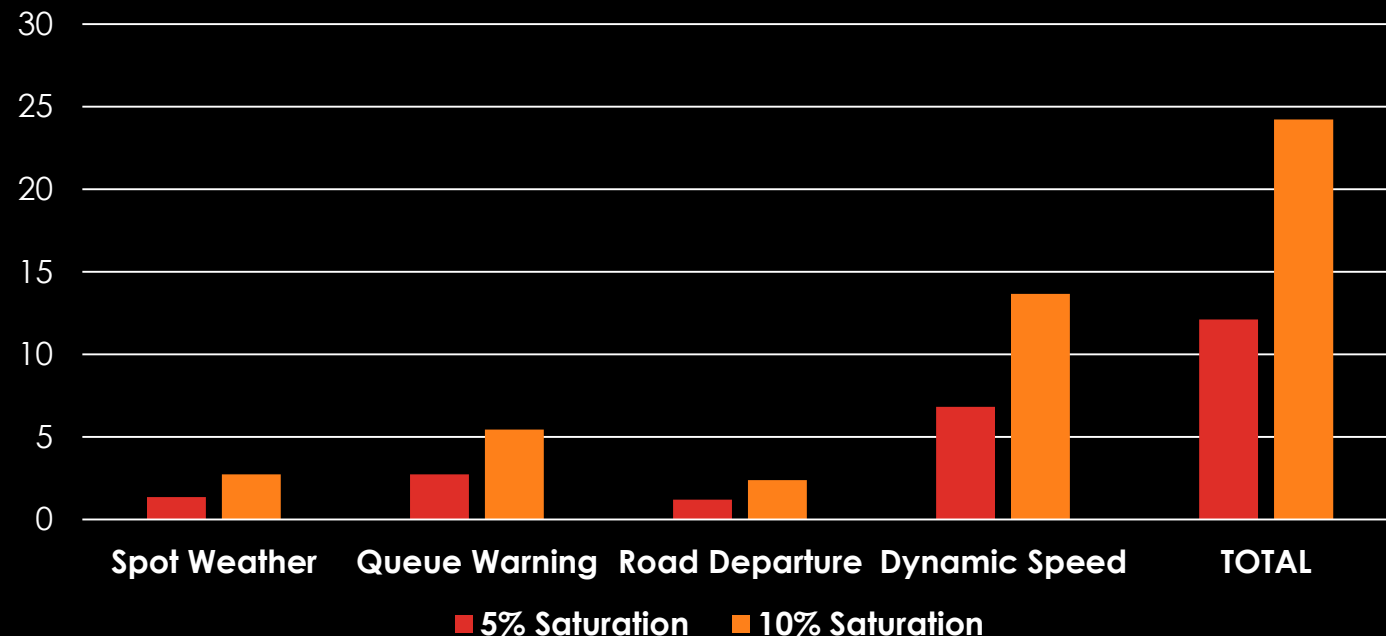
Total Benefit = \$24 million (10%)

Total Cost = \$3,300,000 (\$50k/mile)

**Estimated Benefit/Cost
Ratio = 7.4 to 1**



CV Safety Benefits, I-25 Through Region 1
(\$ millions)





AIR QUALITY ANALYSIS

CV ANNUAL ADDITIONAL EMISSIONS/AIR QUALITY BENEFITS**

Year	CO (tons/yr)	CO2 (tons/yr)	VOC (tons/yr)	NOX (ton/yr)	All Pollutants
2021	24	1,850	1.4	.7	1,876.1
2022	51	3,303.4	2.6	1.3	3,358.2
2023	30.6	1,873.4	1.6	0	1,905.7
2024	34.7	2,656.1	2.3	-.5	2,692.6
2025	10.2	981.3	.8	-.4	992
Total Reduction	150.5	10,664.2	8.7	1.1	10,824.5

**IoR installation (RSUs) and Ecosystem. The dollars per ton/per year for all pollutants reduced in 2021 is \$4,872.00

First-ever methodology created by NavJoy

Conservative Assumptions:

- 5% market penetration in 2021, 15% in 2022, 25% in 2023, 40% in 2024 and 50% in 2025
- DRCOG CMAQ Guidelines default value of 3.5 miles/ hour (MPH) for increase in speed and reduction in pollutants
- Weekday peak periods (6AM to 9AM and 3PM to 6PM) were used (40% of average daily traffic (ADT))
- IoR installation (RSUs) and Ecosystem



STATEWIDE V2X

I2V = Infrastructure to Vehicle
 V2I = Vehicle to Infrastructure
 V2V = Vehicle to Vehicle
 RSU = Road Side Unit

	2017	2018	2019	2020	2021
CONNECTED ECOSYSTEM V2X	Phase 0 Planning \$7 m <i>Funded</i>	Phase 1 V2I \$12 m <i>Funded</i>	Phase 2 I2V \$20 m <i>Funded</i>	Phase ¾ V2V Analytics \$20 m	Phase 5 System integration \$20 m
WHAT ARE WE BUILDING 2017-2021 Statewide Brain + I70	Software Hardware Design Plan	100 Connected Vehicles 120 RSUs Working V2I Software (Quarterly Release)	1700 Connected Vehicles Quarterly Software I2V	1700 Connected Vehicles Quarterly Software V2V Ops Center Integration	Full System + Upgrades in Perpetuity I-70 online STATEWIDE BRAIN BUILT
WHAT DRIVERS/ CDOT GET	Fully Working Pilot	Crash Notification Road Conditions Travel Time Queue Detection	Rerouting Construction Alerts Dynamic Weather Alert Red Light Violation Variable Speed Limits	Snow Plow Priority Full Situational Awareness Emergency Deployment	
ROAD PROJECT EQUIVALENT	PEL/EA	Design Early Action (ROW/ Utilities)	Final Design Early Construction	Construction	Final Project Delivery



BUILDING STATEWIDE V2X SYSTEM

2021





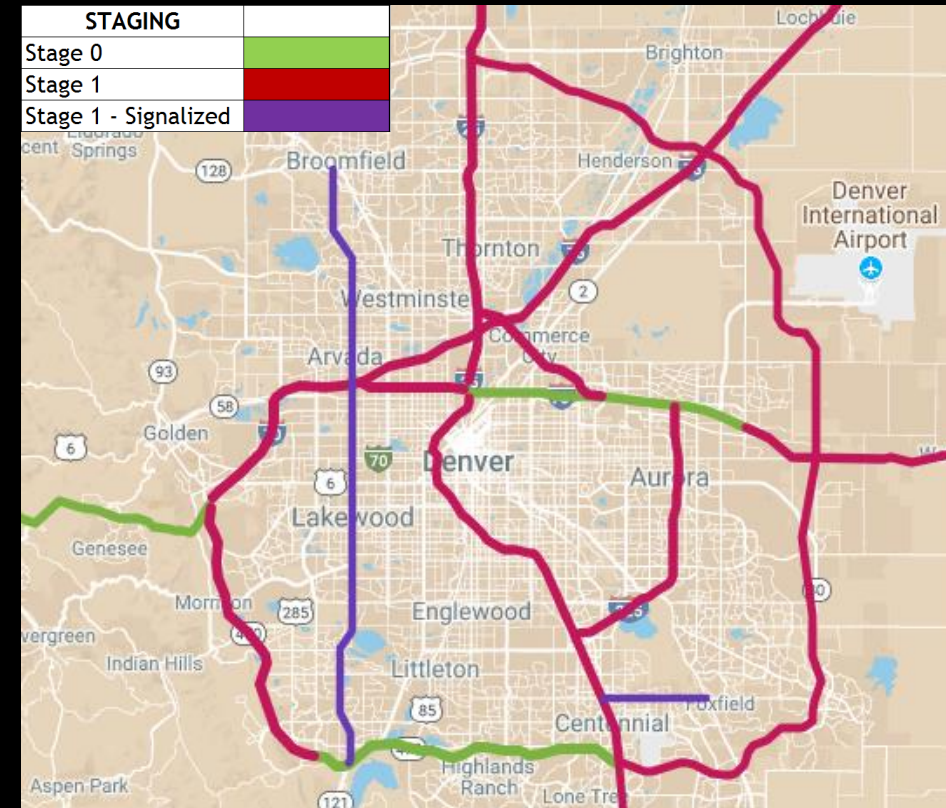
Stage 1 timeline alignment: 2018-2021

500+ miles

Ready for automaker rollout (2021)

Provides smart systems approach

Aligns with Panasonic V2X timeline



		2018				2019				2020				2021			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Stage 0	Design	Green	Green	Green	Green												
	Construction			Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Stage 1	Design				Red	Red	Red	Red	Red								
	Construction								Red	Red	Red	Red	Red	Red	Red	Red	Red
Stage 1 Signalized	Design		Purple	Purple	Purple												
	Construction					Purple	Purple	Purple	Purple	Purple							



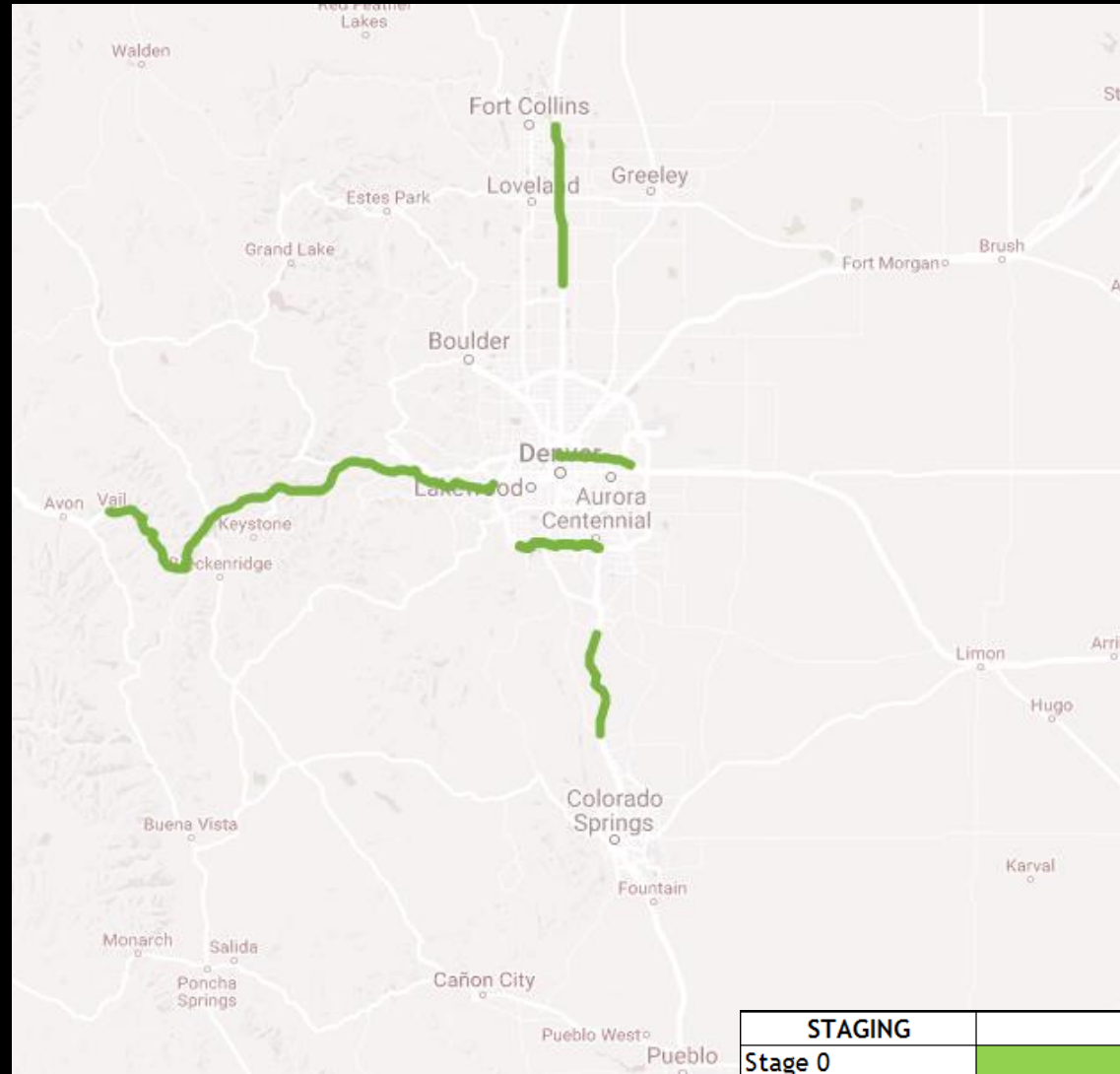
V2X BUILDOUT - STAGE 0

Funded

Total Miles: 200

Managed Lanes, Panasonic

- I-70 W
- I-70 Central
- I-25 N (sect 7-8)
- I-25 S Gap
- C-470





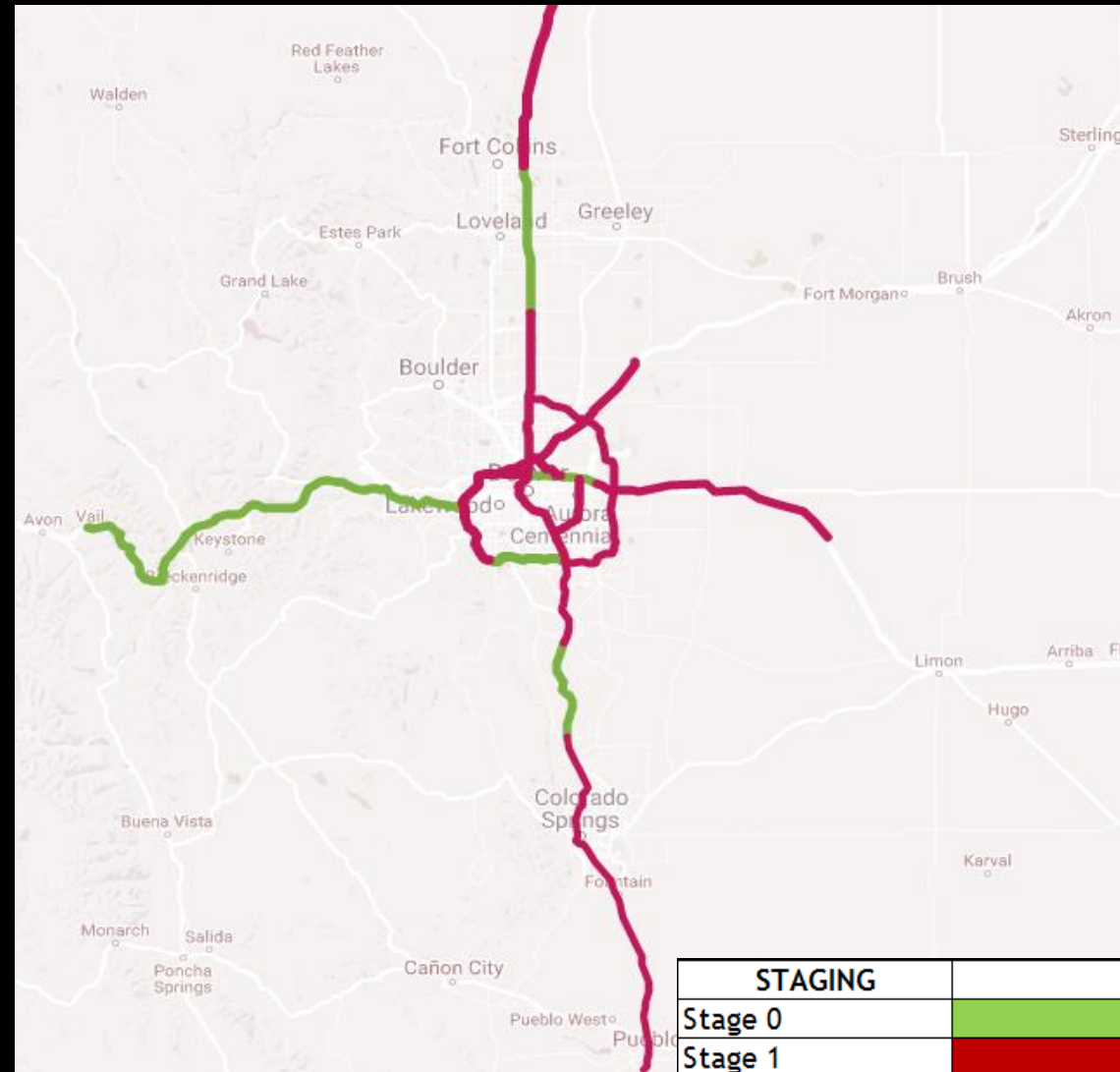
V2X BUILDOUT - STAGE 1

Funded (\$10 million)

Additional Miles: 300

Total Miles: 500+

Stage 1 Cost: \$17 million





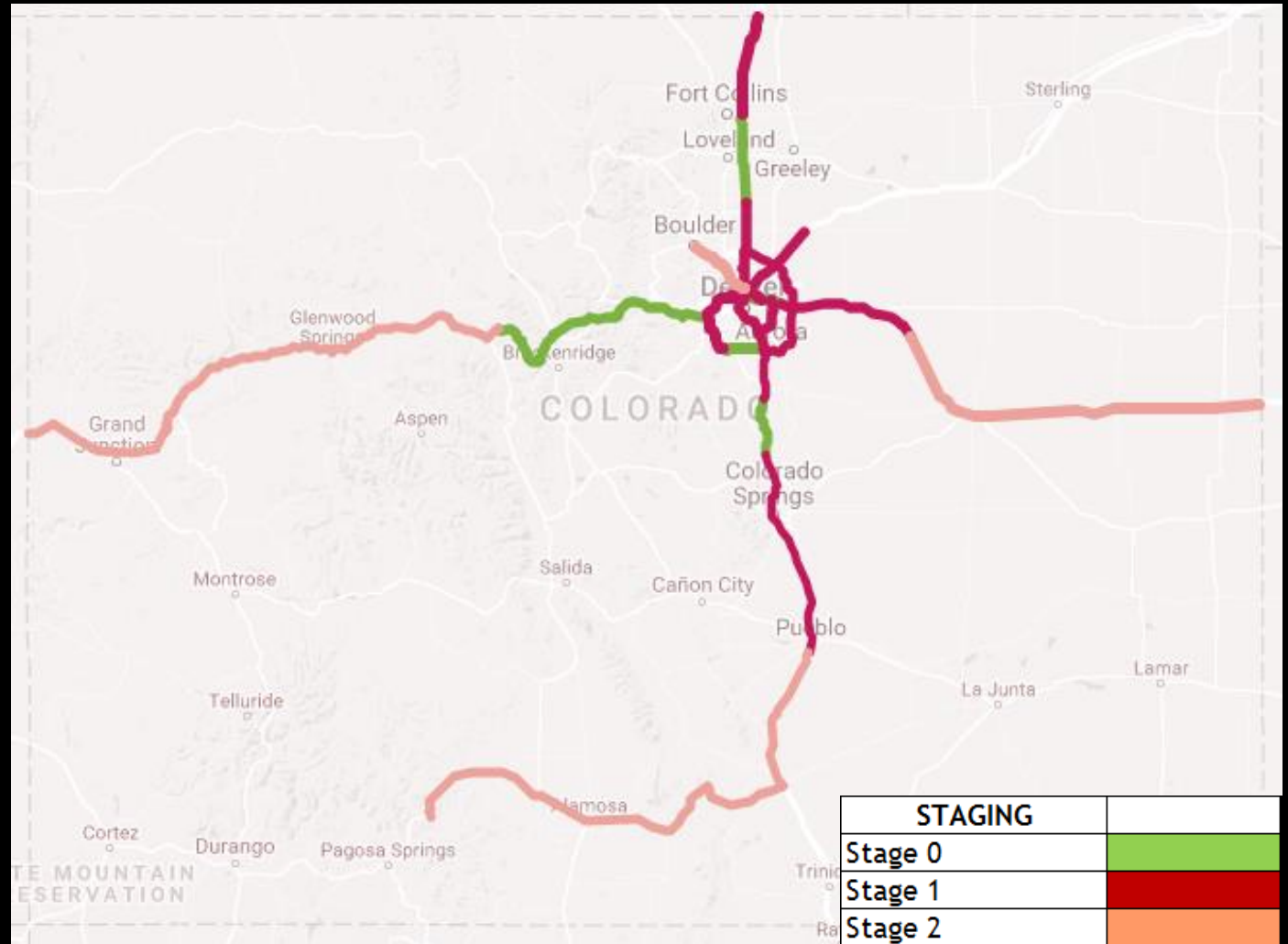
V2X BUILDOUT - STAGE 2

Additional Miles: 500

Total Miles: 1,000+

Stage 2 Cost: \$30M

Total Cost: \$47M





V2X BUILDOUT - STAGE 3

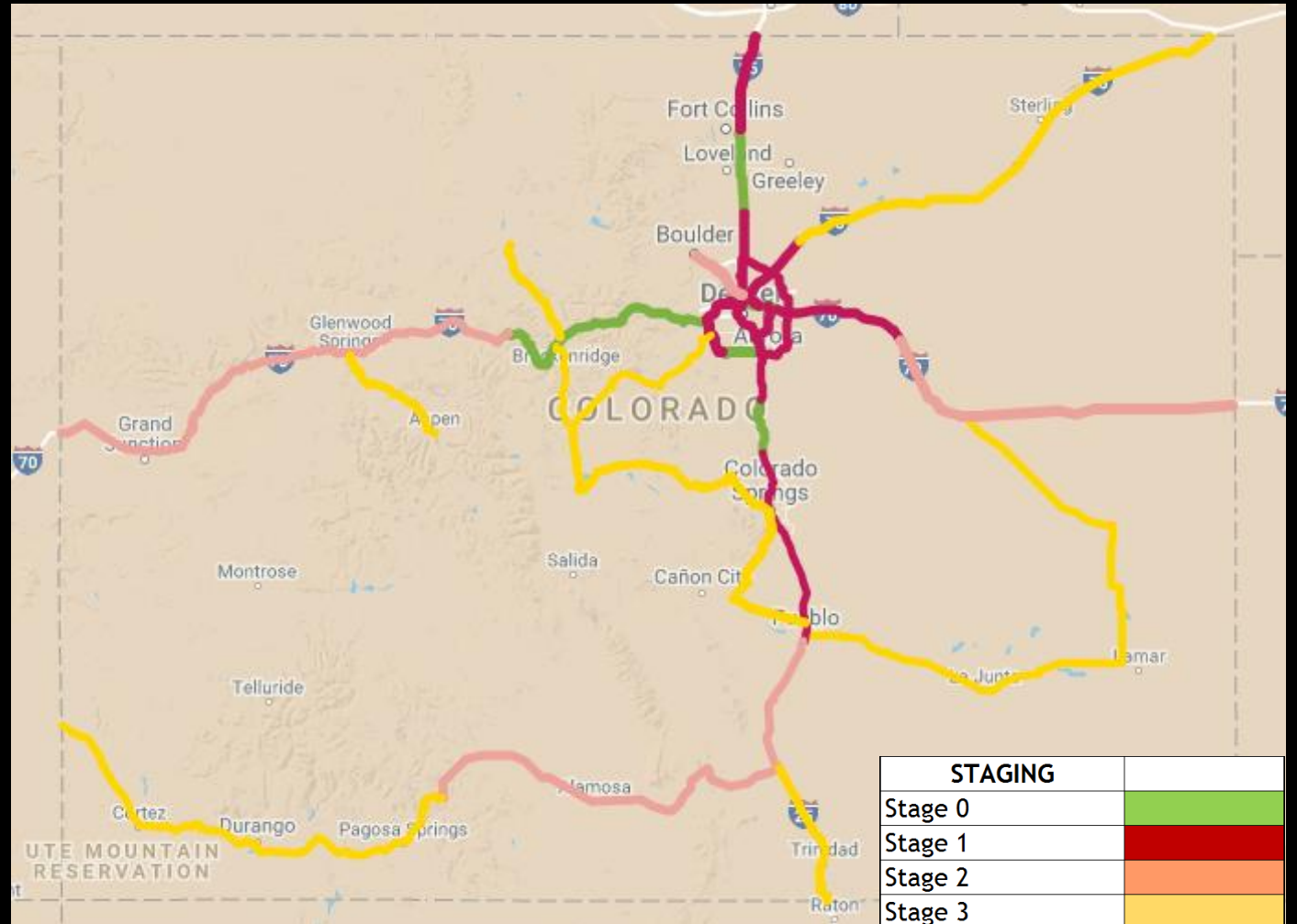
Additional Miles: 1,000

Total Miles: +2,000

Stage 3 Cost: \$250M

Total Cost: \$297M

* Assumes CDOT fiber build, no P3 leveraged funds





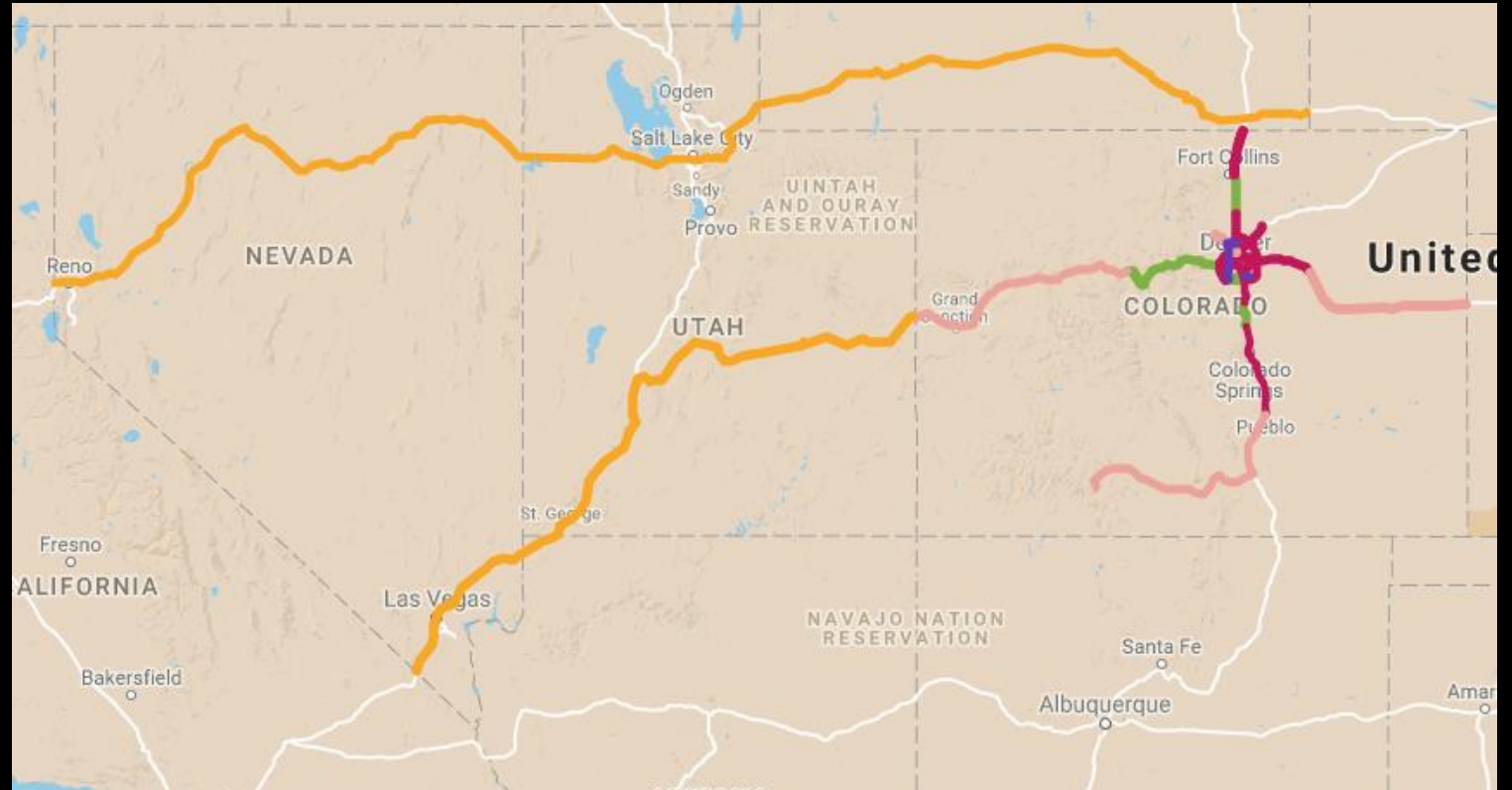
INTERSTATE PARTNERSHIP

Potential for 4 states
CO, WY, UT, NV

I-70, I-15, I-80

1,500 additional miles

2,500 total miles

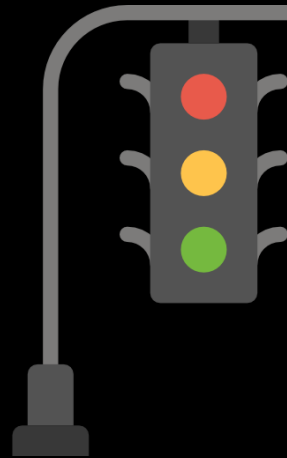




SIGNALIZED CORRIDORS

Additional Considerations

- SPaT and MAP
- Controllers
- Infrastructure
- CDOT Regional Control
- Signal ownership
- Intersection dynamics
- Municipal participation



Additional Applications

- Intelligent/Adaptive Signal Timing
- Signal priority/preemption
- Red light running warning
- Pedestrian in crosswalk
- Dynamic speed harmonization



SIGNALIZED CORRIDORS - STAGE 0

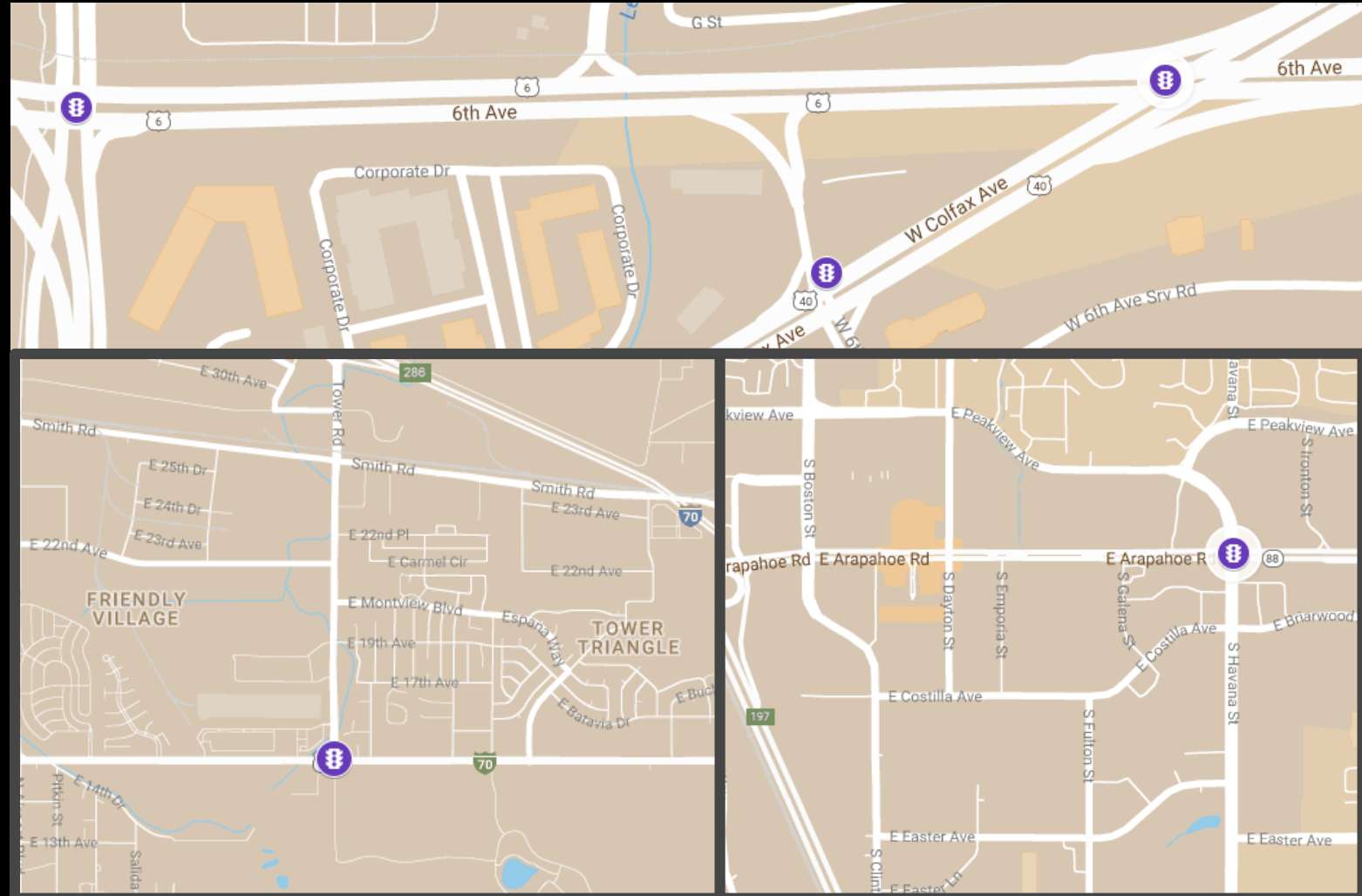
Trial and learn on five intersections

1. Johnson and 6th Ave
2. US40 and 6th Ave
3. Colfax and Interplaza (fleet yard)
4. Arapahoe and Havana
5. Colfax and Tower

**Provide CDOT install expertise,
learning, ownership**

Baseline cost, labor, equipment

SCHEDULE = Summer 2018





SPAT CHALLENGE - STAGE 1

From intersections to corridors

1. Arapahoe Rd
2. Wadsworth

- ✓ Arterials of significance
- ✓ Upgraded signal controllers
- ✓ Fiber

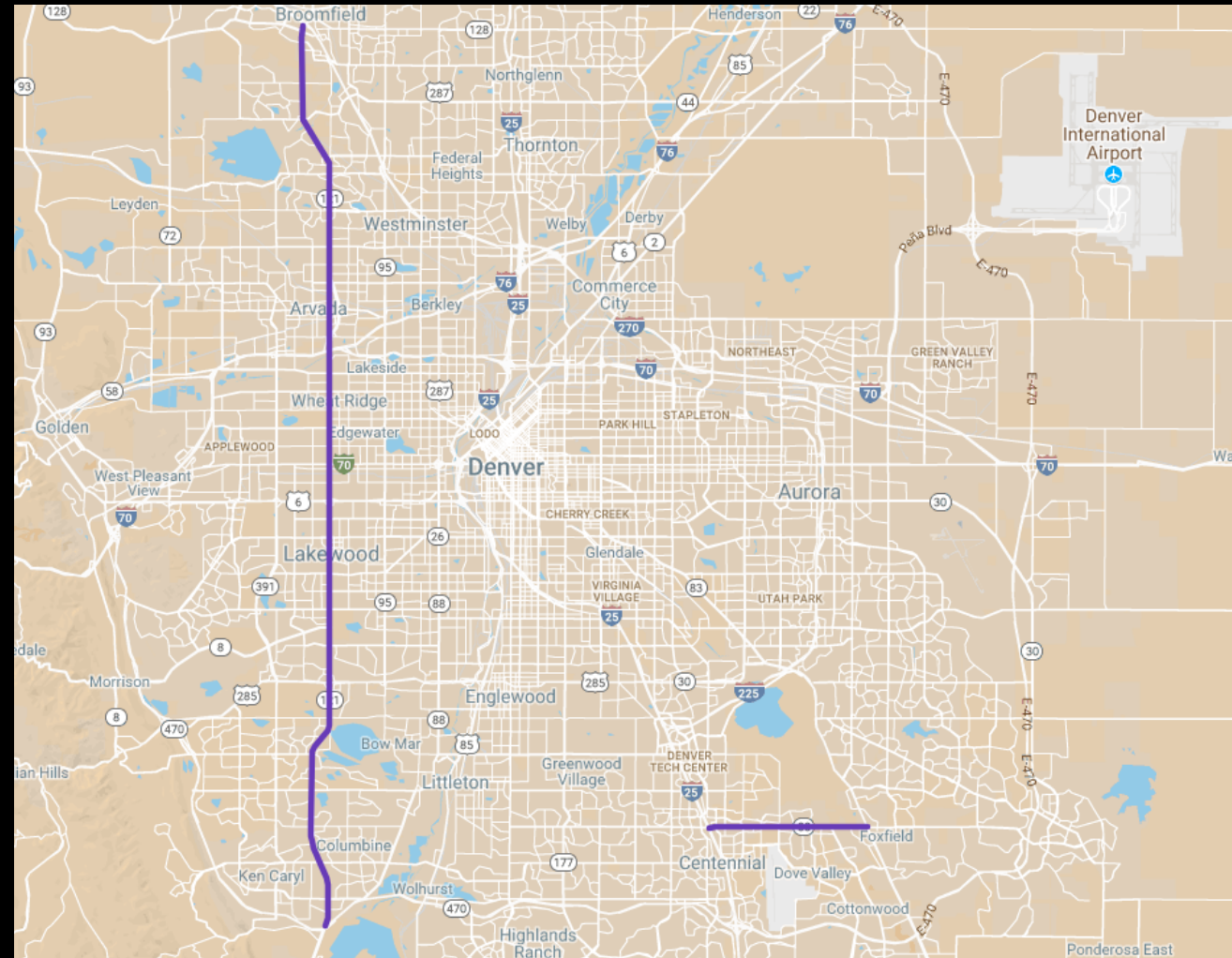
Regional experience

Local CV Integration

Design starting ASAP

Snowplow Priority

FHWA AID grant application





DENVER METRO SIGNALIZED CORRIDORS - STAGE 2

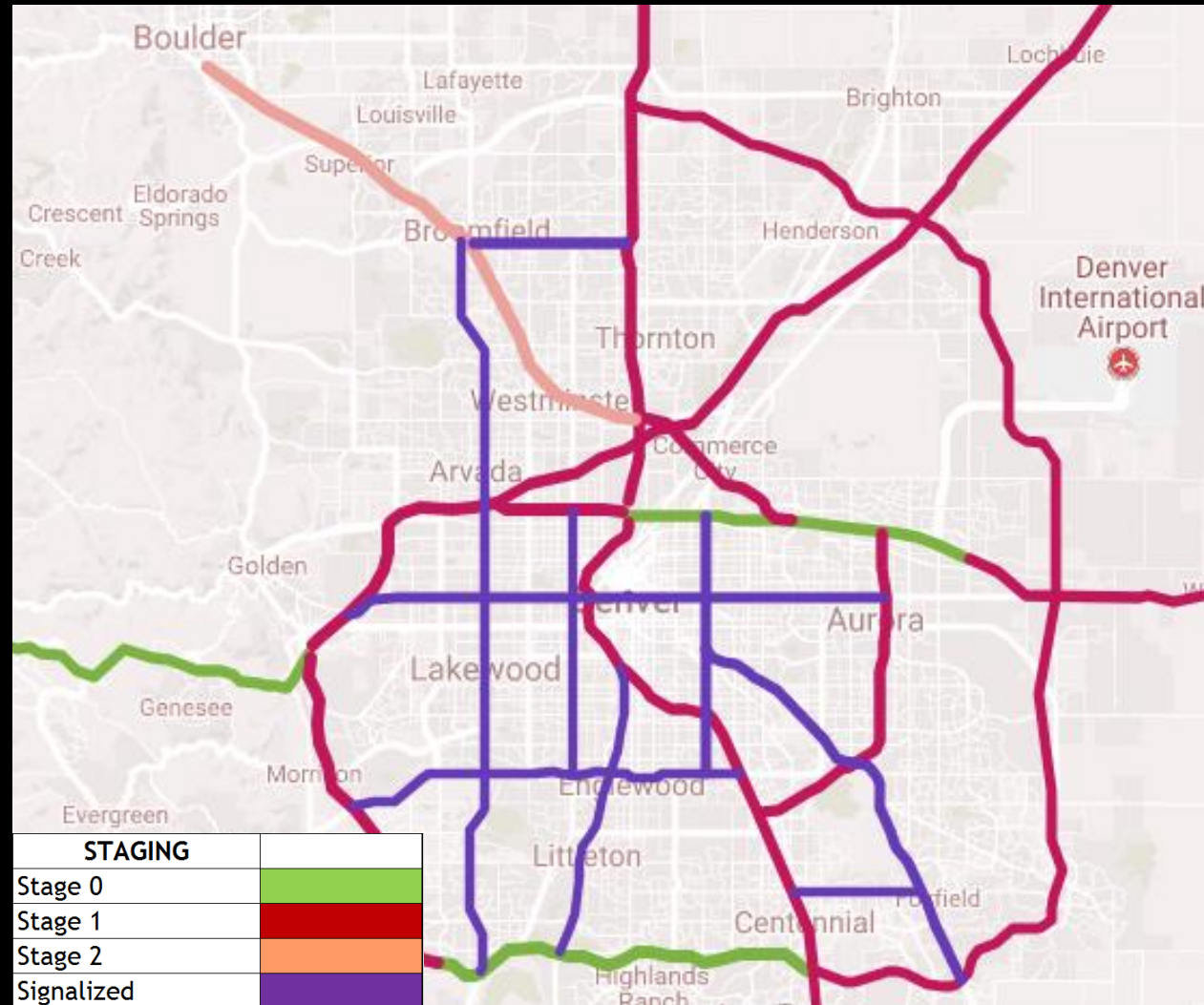
Analysis underway (corridors not proposed yet)

Scale from SPaT Challenge

Lower cost – complete R1 coverage possible

Fiber needed on some corridors

2020-2022





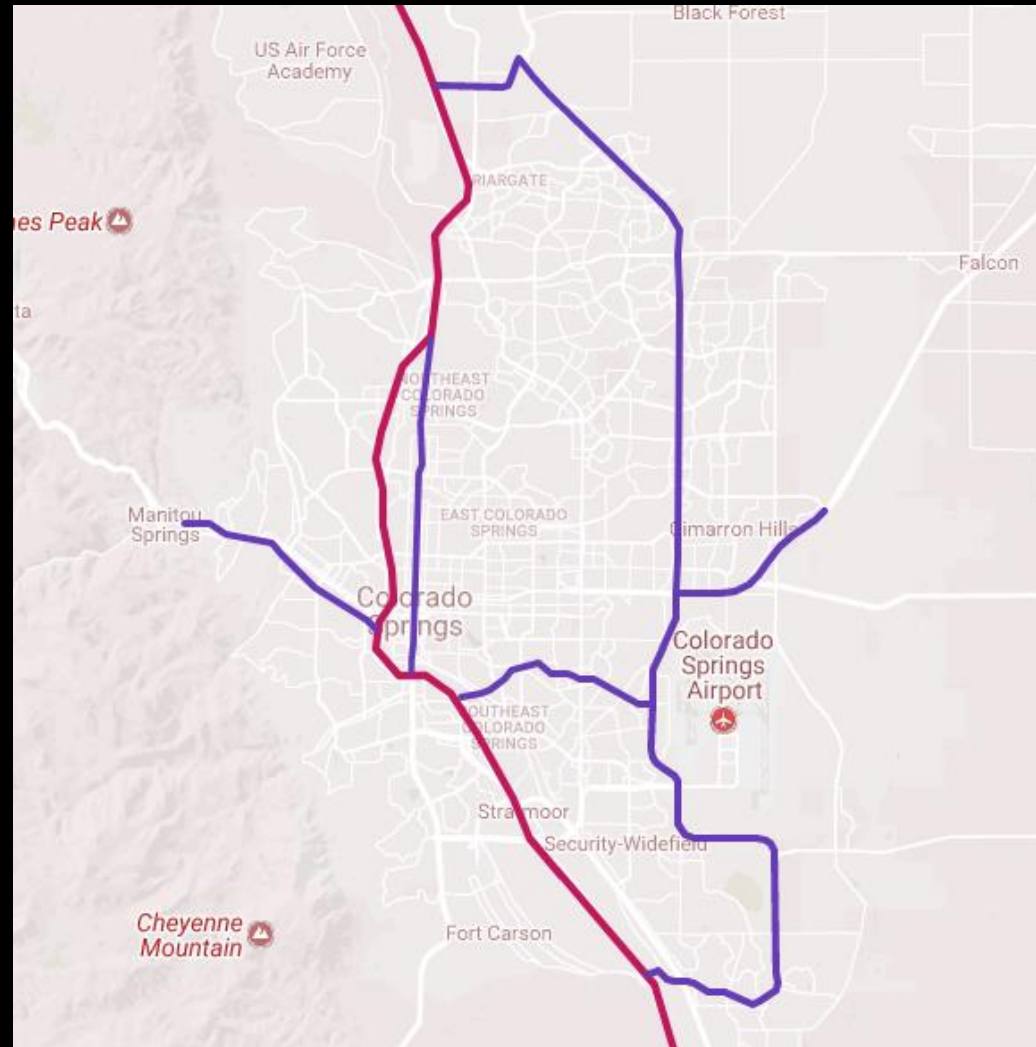
COLORADO SPRINGS SIGNALIZED CORRIDORS - STAGE 2

Major corridors

Metro area coverage

City partnership potential

Analysis TBD





PERSPECTIVE

Nation's first methodology for selecting CV corridors

Nation's first large-scale deployment

Industry-moving potential

Pennies on the dollar compared to new physical infrastructure

Flexible and adaptable infrastructure for virtually limitless roadway applications





DISCUSSION