



Co-Optimization of Vehicles and Routes (CoVaR)

To Improve Commercial Transportation System Efficiency

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PACCAR Inc.

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Project ID eems108

Timeline:

- Start: October 2020
- End: December 2023
- 20% Complete

Budget:

- Total project funding: \$2.5M
 - DOE: \$2M
 - Cost Share: \$500,000
- FY2021 Funding: \$1.2M

Barriers:

- Business Incentives for Cloud-Providers, OEMs, and Fleets
- Vehicle to Cloud Architecture Technologies
- Network Bandwidth

Partners:



Objectives:

- 25% Fleet Freight Efficiency Improvement
- Develop, Implement, & Validate Advanced Connected Transportation Systems
- Powertrain Agnostic:
Diesel and e-Powertrain



Impact:

- Improve Fleet Freight Efficiency Through Various Connectivity Systems:

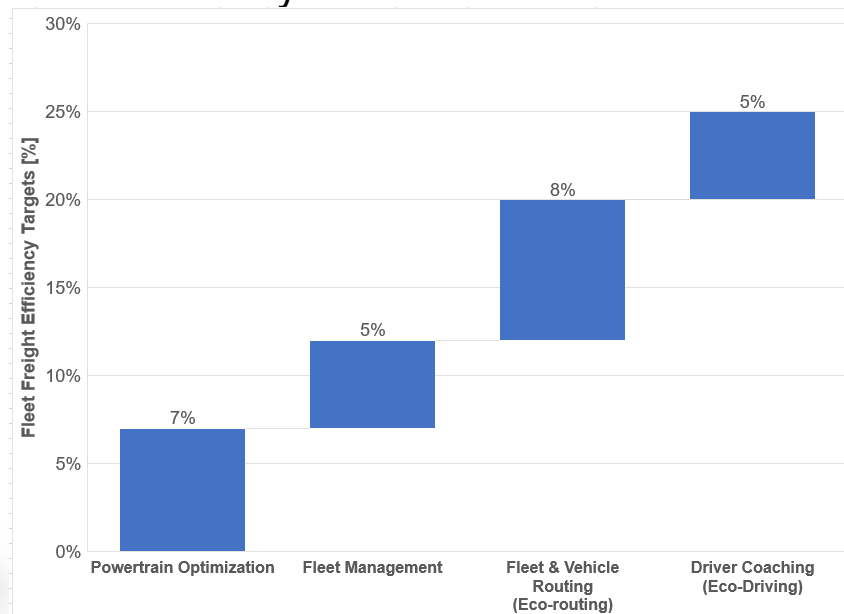
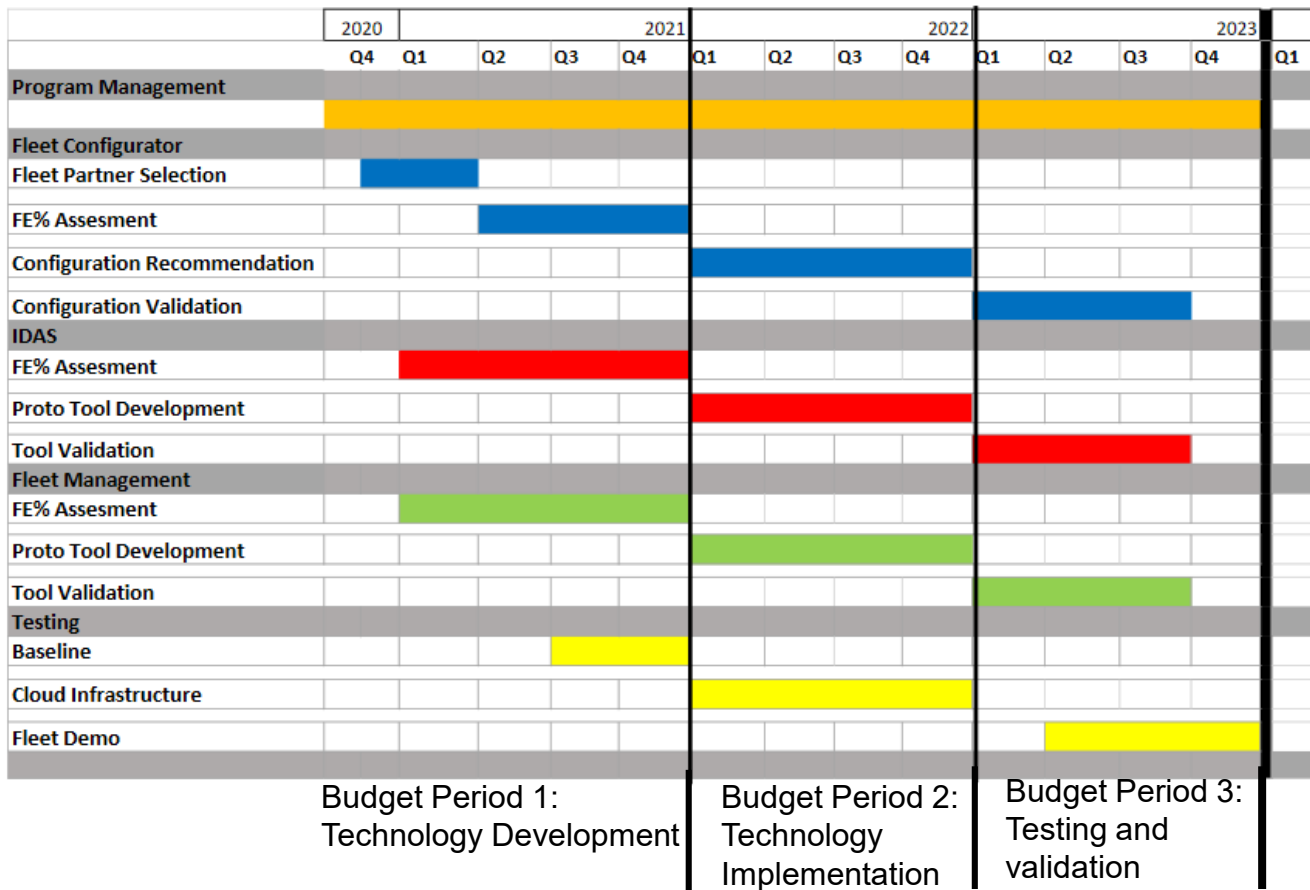


Chart Showing Fleet Freight Efficiency Targets

Program Outline



Budget Period 1:
 10/01/2020 – 12/31/2021

Budget Period2:
 01/01/2022 – 12/31/2022

Budget Period 3:
 01/01/2023 – 12/31/2023

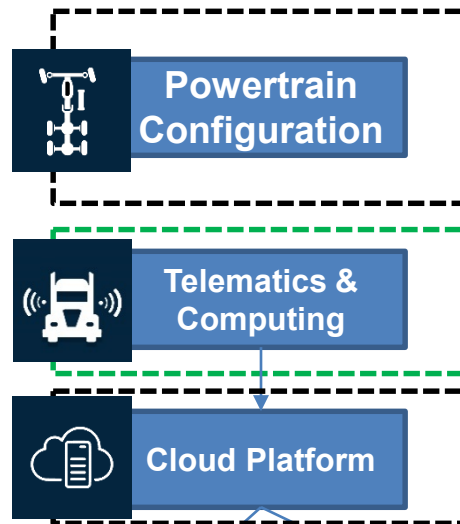
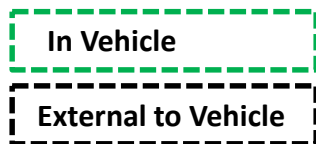
Budget Period 1: October 2020 - December 2021

| Milestone | Description | Status |
|--|---|--------|
| Baseline Freight Energy Efficiency Quantified | Number of Current Freight Energy Efficiency in Appropriate Units | 25% |
| Selection of Fleet Partner | Ideally by M3-M6, latest by M12 | 50% |
| Intelligent Driver Assistance System Assessment | Assessment of Intelligent Driver Assistance System's Ability to Meet Freight Efficiency Target | 10% |
| Fleet Management System Assessment | Assessment of Fleet Management System's Ability to Meet the Freight Efficiency Target | 10% |
| Vehicle Configuration Optimization System Assessment | Assessment of the Vehicle Configuration Optimization System's Ability to meet the Freight Efficiency Target. | 40% |
| Baseline Testing on Commercial Fleet | Simulate CoVaR Technology on a Commercial Fleet to Determine if Freight Efficiency Improvement is achievable and manufacturable | 10% |

Approach

Integrate Several Pieces of Technology to Optimize:

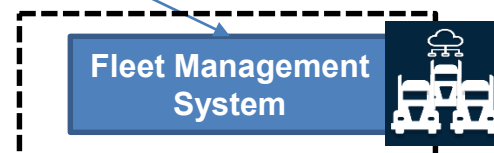
- Powertrain Configuration
- Eco-Routing
- Driver Efficiency
- Fleet Management



- Find the optimized powertrain based on a set of criteria or customer requirements
- Perform data collection and computing required for route optimization and driver efficiency
- Send data to cloud platform for use by other systems

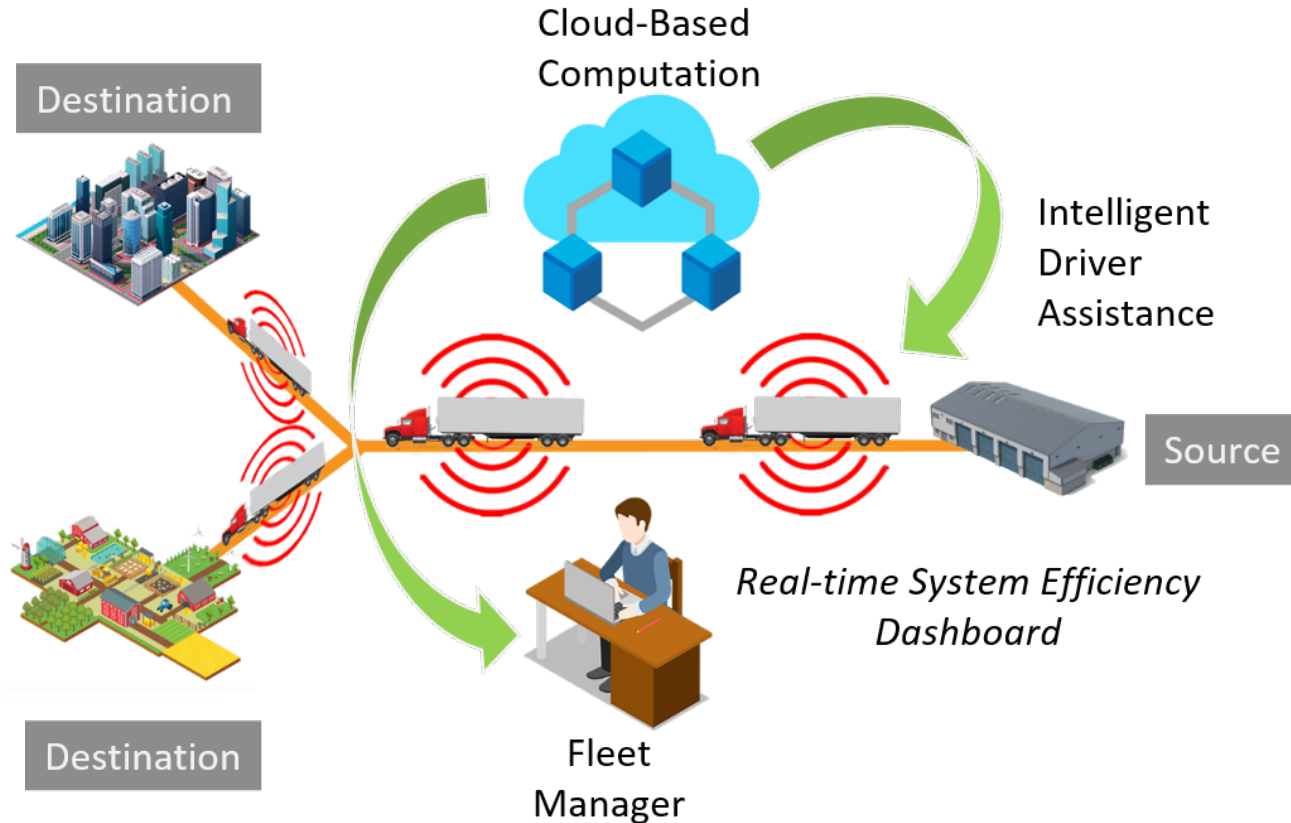


- Provide driver coaching based on performance data



- Provide fleet dashboard to better understand fleet performance

Approach



Fleet Partner Selection

Milestones:

- Defined Key Requirements
- Shortlisted Three Potential Fleet Partners



Summary:

- A Fleet Partner That Meets Requirements is a Key Piece for This Program

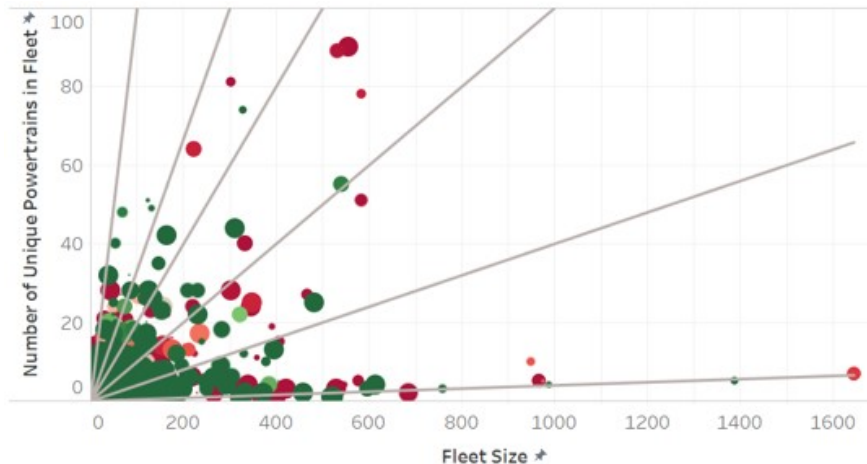
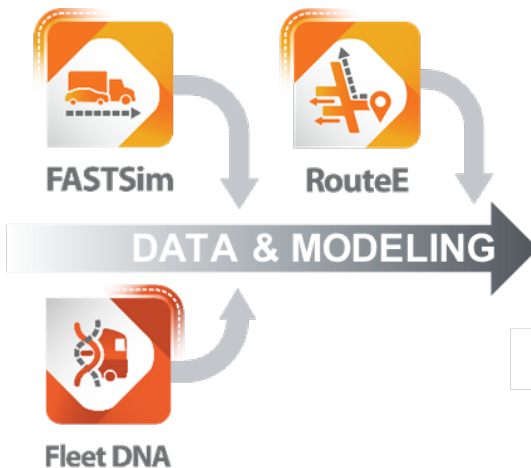


Chart showing # of unique powertrains versus fleet size

Fleet Data Analysis & Energy Consumption Prediction



**CUSTOMER
RECOMENDATION
AND FEEDBACK**



Powertrain Optimization

Milestones:

- Simulation Framework Defined
- Conventional Powertrain Simulator Developed
- Machine Learning Models Beginning to be Trained

Summary:

- The Powertrain Configuration Optimization Model Predicts the Engine Power Required to Meet Specified Customer Requirements

DATA-DRIVEN SIMULATION-ASSISTED POWERTRAIN RECOMMENDER SYSTEM

Inputs and Constraints

Performance requirements
Route information
Freight capacity

Database

Real-world driving **data**
Drive cycles **simulations**
Powertrain components

Machine Learning Models

for Powertrain Specification
and Energy Consumption
Prediction



Powertrain Specification Optimization

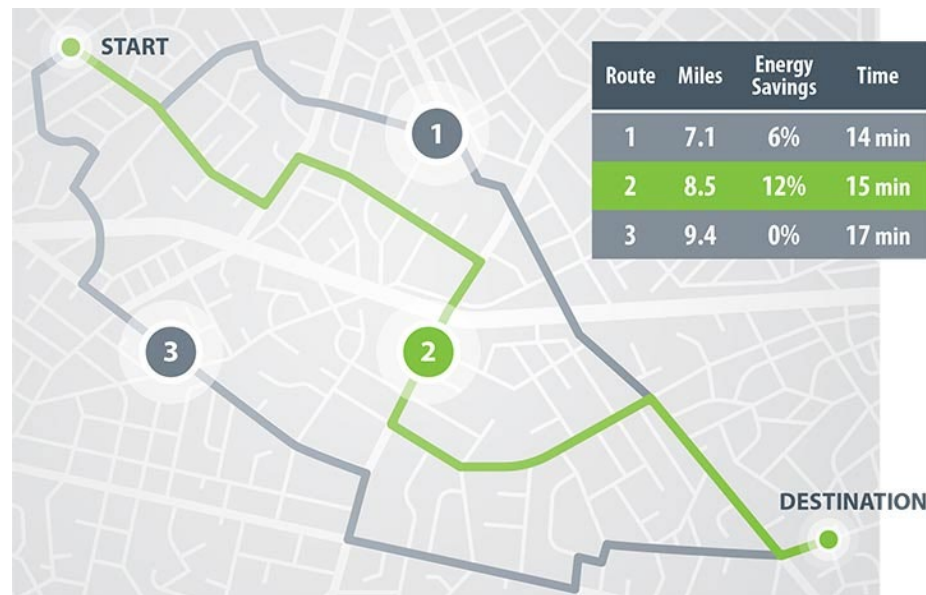
Fulfill customer requirements
Efficient for one or more objectives

Milestones:

- Developed a Methodology for Testing Energy Cost and Eco-routing Integration
- Data Collection Started From Development Trucks for Proof of Concept

Summary:

- Utilizing NREL and Esri's Routing Capabilities Will Allow for Drivers to Find the Most Energy Efficient Route, Real-time and In-vehicle



Example of NREL's RouteE tool

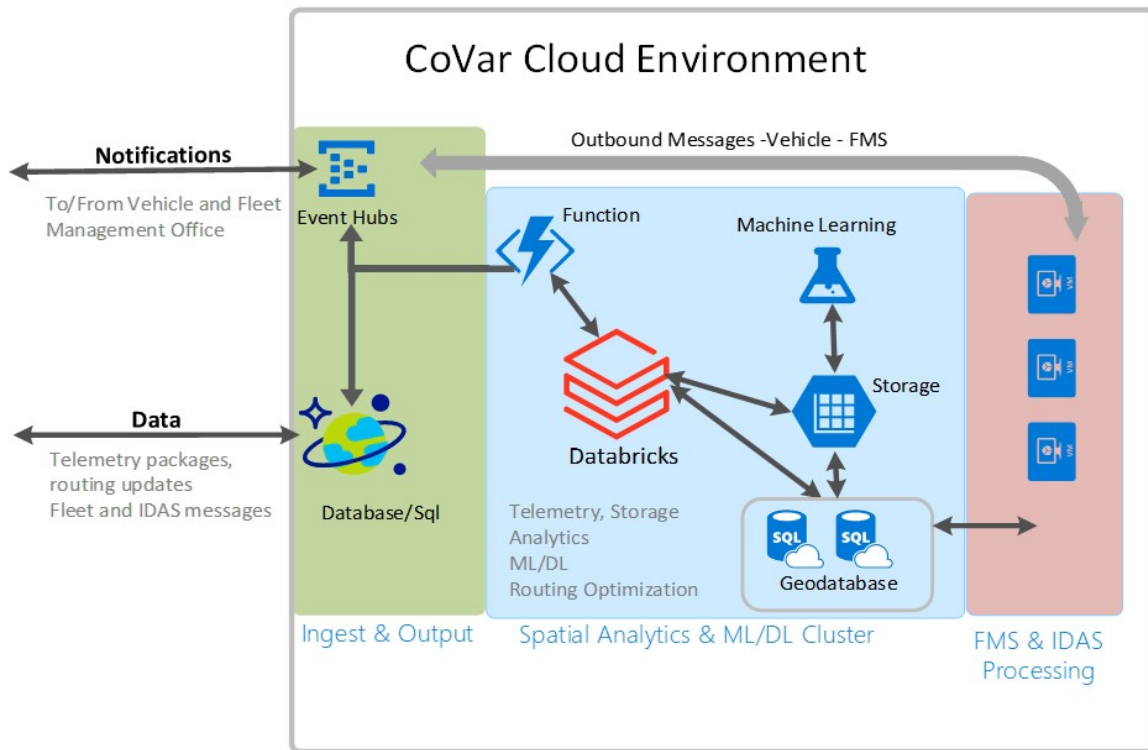
Cloud Architecture

Milestones:

- Overall Cloud Architecture Defined
- Created a New Tenant to Allow for Infrastructure to be More Easily Allocated to Other Teams

Summary:

- Initial Cloud Architecture has Been Defined and is a Critical Piece to the CoVaR Technology Package



Cloud Architecture Diagram for CoVaR

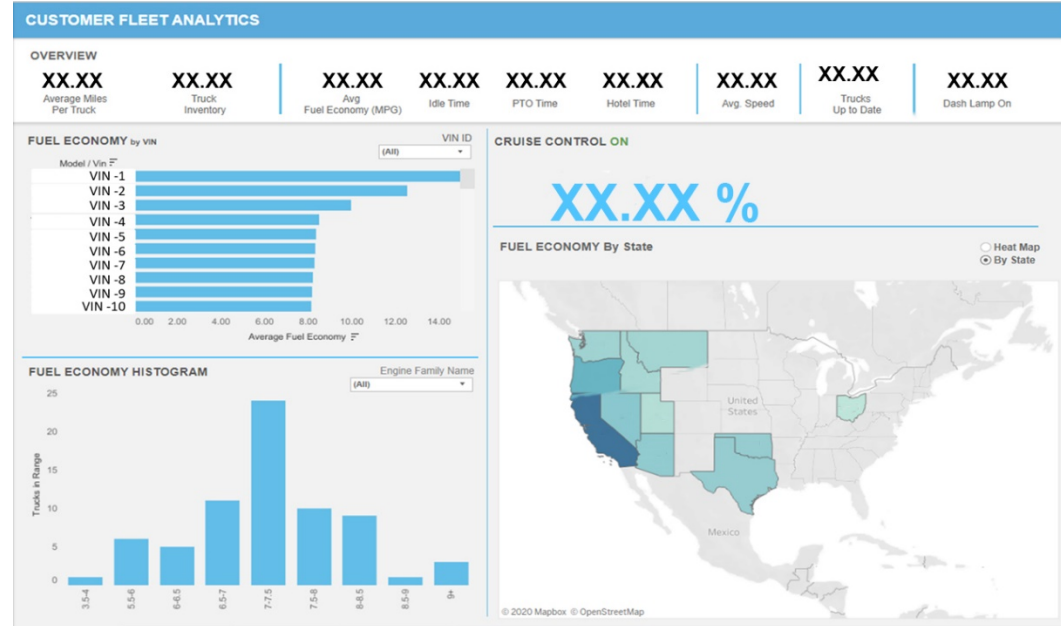
Fleet Management System

Milestones:

- Developed an Early Simulated Demonstration of the Fleet Management Dashboard
- Developed Architecture for Dataflow for FMS and IDAS

Summary:

- First Iteration of the Fleet Management Dashboard Based on Simulated Data has Been Completed



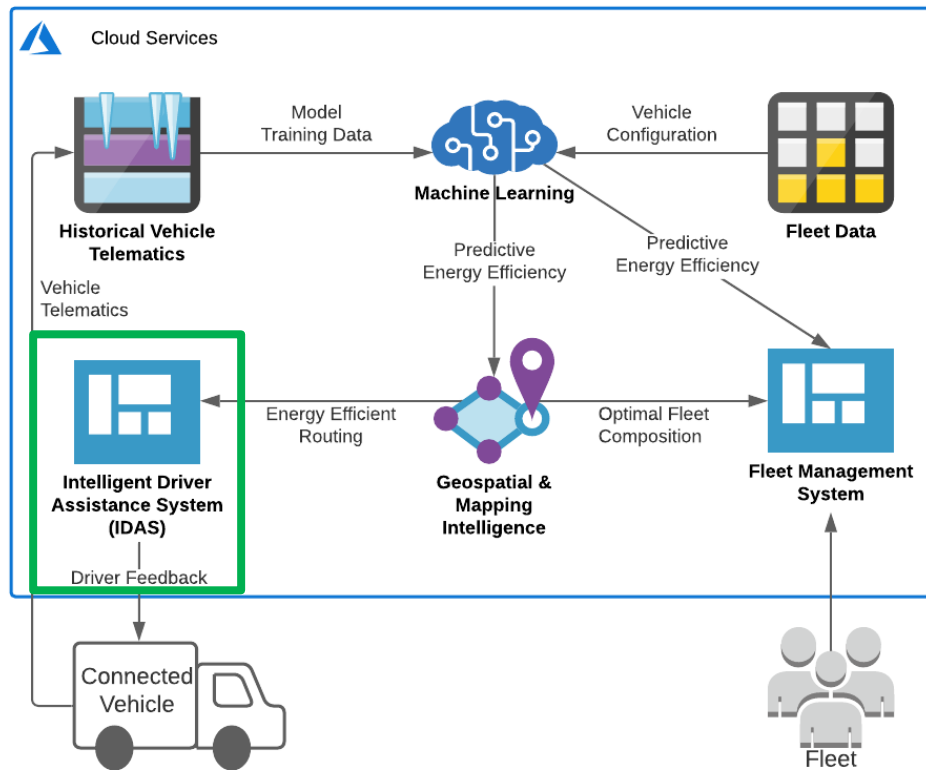
Intelligent Driver Assistance System

Milestones:

- Human Centered Design Workshops to Define Design Constraints
- UX/UI Development Process Defined
- Defined Potential Data Flow for IDAS and FMS
- First Iteration of IDAS Display

Summary:

- IDAS Architecture and UX/UI Framework Have Been Developed



Architecture Diagram for CoVaR Technology

- This is the First Year That the Project has Been Reviewed

Partnerships and Collaborations



- Kenworth: Vehicle Deployment, Fleet Partnership



- NREL: Fleet Data Analysis, AI Routing, Route Optimization,



- OSU: Powertrain configuration optimization



- Valence: Fleet Management System and IDAS



- Esri: Cloud Architecture and Routing

Remaining Challenges and Barriers



Main Barriers:

- Finalizing Fleet Partner for Field Test Validation and Deployment
- High Cost of Telematics and Onboard Compute for Fleet Applications

Technical Challenges:

- Seamless Integration of Connectivity, Compute, Artificial Intelligence, and Human Machine Interaction on Vehicle
- A-B Testing of Technologies on Fleet, Engaged in Active Commercial Transportation

FY21: Technology Development

- Implement Proof of Concept Technology Integration Onto Two Demonstrator Vehicles
- Finalize Fleet Partnership
- Continue Iterations on FMS, IDAS and Powertrain Optimization
- Evaluate Telematics Hardware for Field Test

FY22: Technology Implementation

- Continue Validation With Demonstrator Vehicles
- Implement Technology Package Onto Fleet Partner Vehicles
- Validate Technologies on Field Test Vehicles

Any Proposed Future Work is Subject to Change Based on Funding Levels.

Accomplishments:

- Initial Architectures and Frameworks Defined for Key Technology Components
- Shortlisted 3 Potential Fleet Partners
- Conventional Powertrain Simulator Developed
- First Iteration of Fleet Management Dashboard

Impact:

- Potential for 25% Freight Efficiency Improvement
- Integrates Several Connectivity Technologies Which Builds Potential for Future Projects
- Powertrain Agnostic Which Makes This Technology Applicable for More Vehicles