# AI-Powered Cloud and Fog for Teleoperation of Autonomous Vehicles

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# What's Happening to Autonomous Cars Now

## I. Drive Themselves

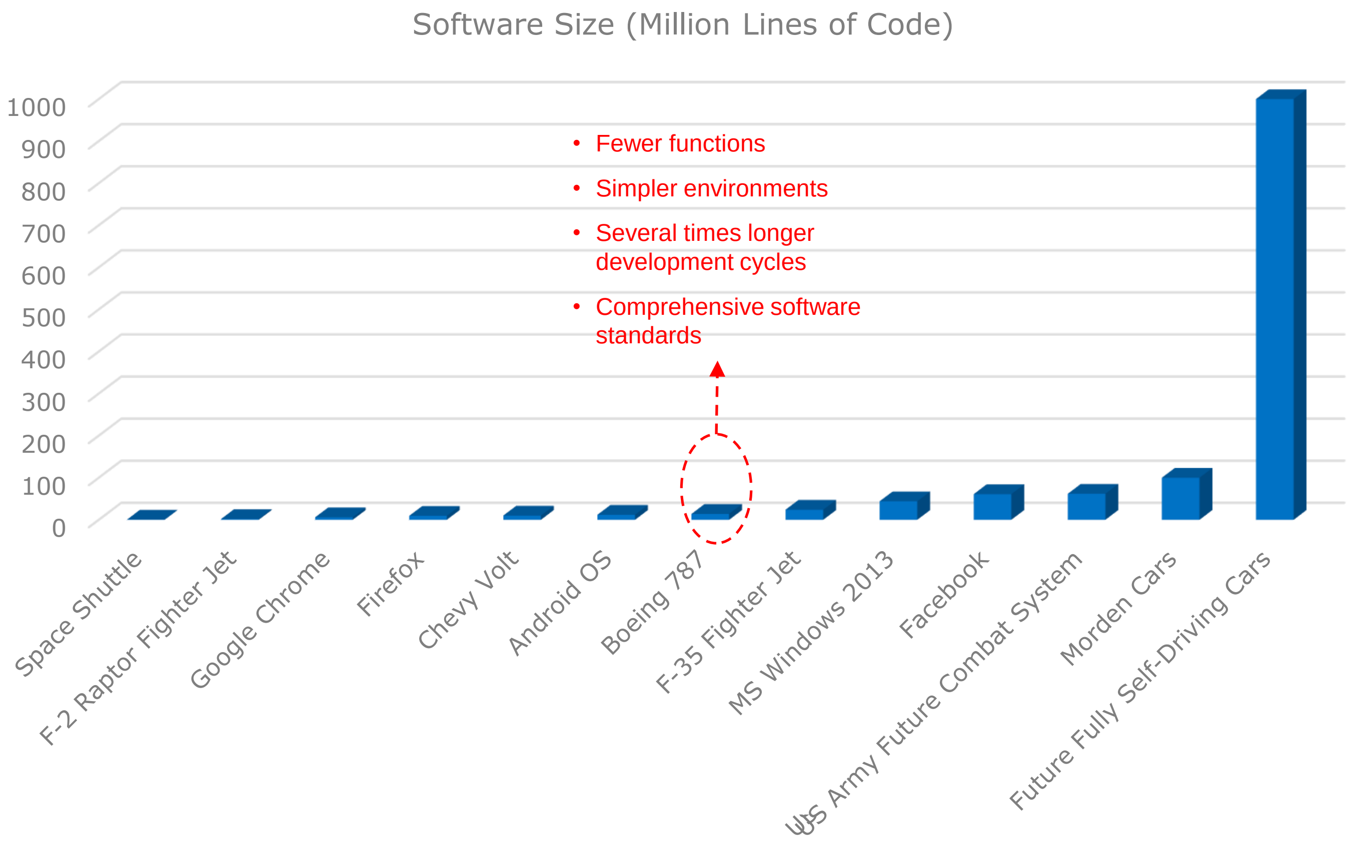
1. Perception
2. Prediction
3. Decision Making
4. Onboard Computing Platform
5. Testing

## Fundamental Challenges Make Fully Self-Driving Cars a Distant Target

1. **Self-driving algorithms**: Handle excessively large range of driving scenarios
2. **Software**: Make extremely large & complex SW on every car auto-grade
3. **Security**: Meet car requirements current security paradigm not designed for
4. **Integration** with transportation system: Barely started
5. **Testing and validation**: An intractable mission now
6. **Standards** and regulations: Lots to catch up

1. **High complexity and costs, low reliability and manageability of vehicles**
2. **Long wait for benefits: L5 or widely deployable L4 likely take years or decades, meanwhile human drivers must stay in cars**

# Cars Run on **Complex** Software Systems



# We Now Face a Steep Cliff: Is There a New Path?

# The Rise of the Cloud for Automated Driving

## So Far
## Cloud **Assists** and **Uses** Self-Driving Cars

### Assist

- ❑ Train ML models
- ❑ Monitor
- ❑ Update SW
- ❑ Provide info
- ❑ Provide Internet services

### Use

- ❑ Mobility services

***Cars drive themselves***

## Future
## Cloud will also **Drive** and **Protect** Cars

### Drive

- ❑ Remote driving assistance
- ❑ Remote commanding
- ❑ Remote driving

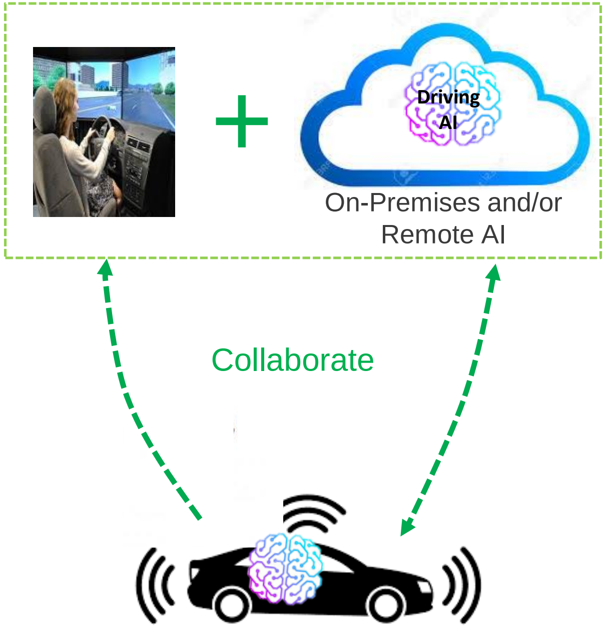
### Protect

- ❑ Remote monitoring and threat detection
- ❑ Remote incident response

***Cars get help from Cloud to drive***

# Cloud Driving and Teleoperation

**Going forward**
we envision moving some automated driving intelligence into the cloud




1. Vehicles: lower complexity, lower costs, higher reliability, and higher manageability
2. Benefits NOW, and along the way
3. A new path to to automated mobility
4. Necessary for self-driving cars of any automation levels

# Different Forms of Cloud (Remote) Driving

- Cloud-based Driving Assistance: Cloud services to assist human teleoperators, or to augment or execute some driving tasks or parts of a driving task while the car or its human teleoperator drives the car
- Cloud-based Commanding: Cloud services issue high-level driving commands or instructions to a car while the car executes the driving task on its own
- Cloud-based Driving: Cloud services take over control of some or all driving tasks of a vehicle

# Evolution to Revolution with Value Along the Path

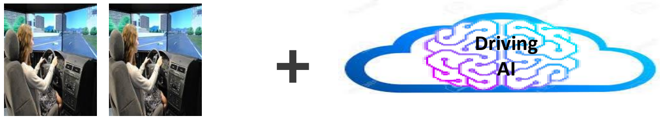
## Fully Automated Cloud Driving

- L4-5 cloud driving
- Human teleoperators for monitoring and emergency
- Low cost, high reliability, high manageability of the vehicle


**Few**
Human Teleoperators

**Fully Automated**
Cloud Driving Brain

## Evolution




**Fewer**
Human Teleoperators

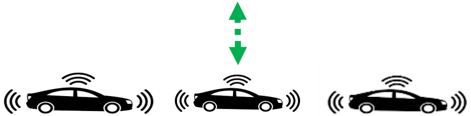
**Bigger and Growing**
Cloud Driving Brain

- Reduced dependency on human teleoperators
- More driving scenarios and use cases
- 1-to-N teleoperation

## Initial Phases


**All**
Human Teleoperators

**Small**
Cloud Driving Brain



- Move human drivers out of cars to safer and more conformable places
- Provide necessary remote management and assistances to AVs
- Enable a new mobility paradigm: anyone can drive any car
- Use existing cars to deliver L4-5 functionalities
- Lower vehicle software complexity and costs

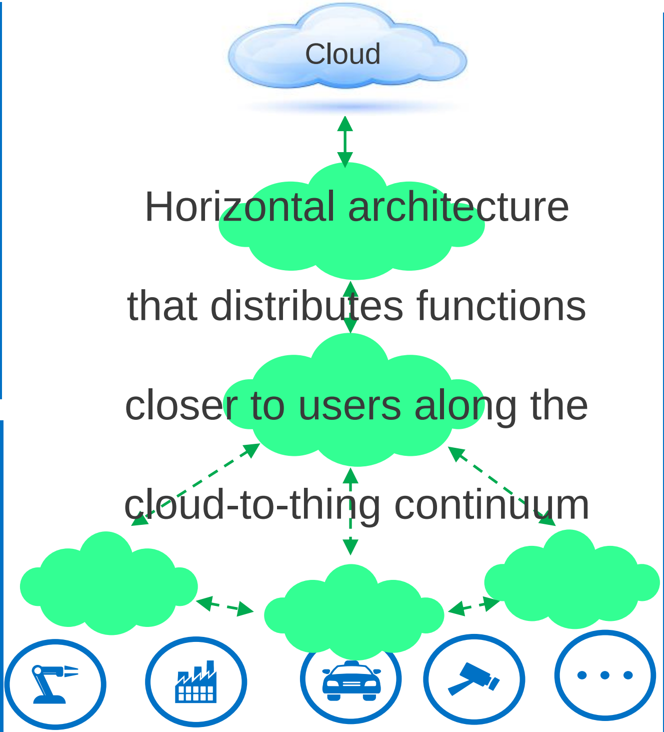
# Entering the Era of Fog Computing

## Horizontal Architecture

- Support multiple network types and industry verticals

## Works Over and Inside Wired or Wireless Networks

(No need for siloed systems just for moving computing around inside each specific network such as 5G)




## Cloud-to-Thing Continuum of Services

- E2E architecture to make computing possible anywhere along the continuum

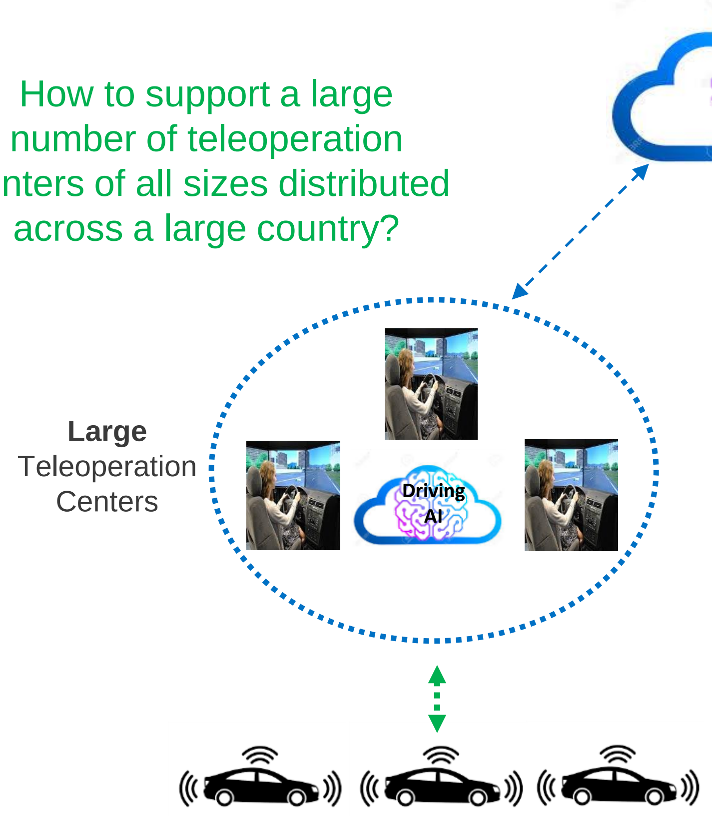
  (Not just placing siloed servers, apps, or small clouds at the edge)

- Seamless integration with the clouds and things

  (Not isolated edge devices or apps)

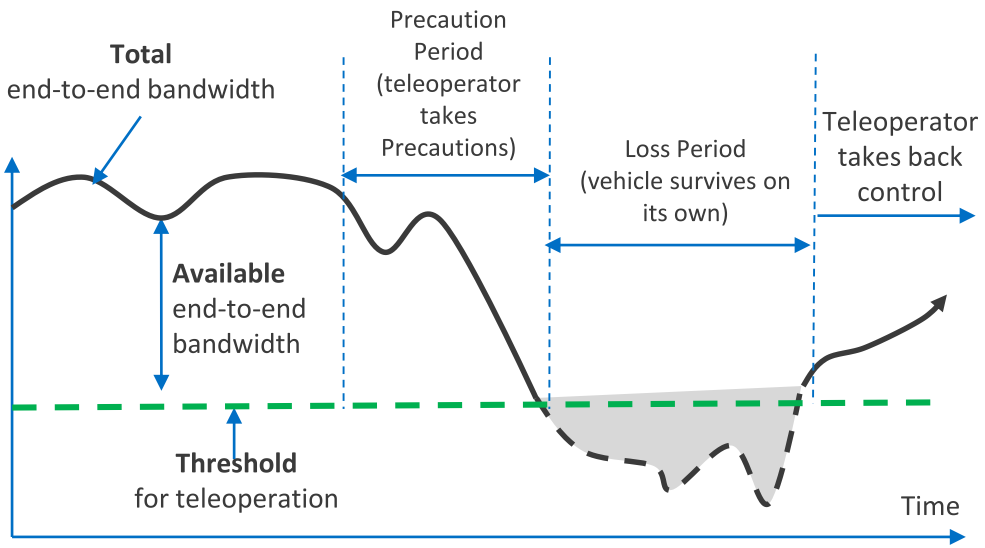
# Cloud/Fog Architecture for Teleoperation

How to support a large number of teleoperation centers of all sizes distributed across a large country?



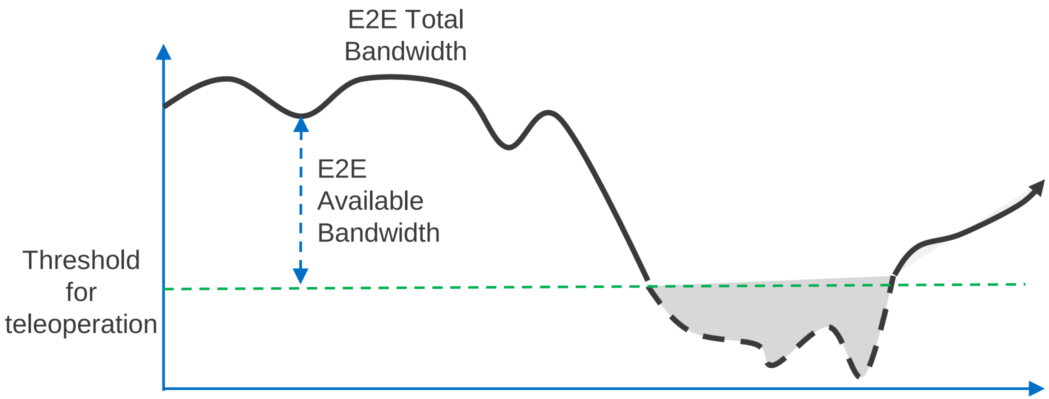
# What Happens When Network Performance Becomes Bad?

**Conventional Approaches** typically build statistical models of E2E delay and available bandwidth to predict when they may drop below thresholds




1. Difficulty modeling precaution periods – as they depend also on road conditions
2. Difficult to accurately predict long enough into the future

# Machine Learning for Fail-Safe Teleoperation




Present estimated E2E delay and available bandwidth to human teleoperators

Record human teleoperators' actions (start and finish times of different actions)

Training Data

Extract Driving Scenarios

Build ML Model of **Precaution Periods** for Each Driving Scenario

Build ML Model of **Loss Periods** for Each Driving Scenario

Build models based on highly related history

# Thank You !