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Safe. Clean. Affordable.

Hardware-Enabled Data Analytics

Using Advanced Leak Emissions Measurement Tools and Data Analytics to Help Manage Your DIMP Program

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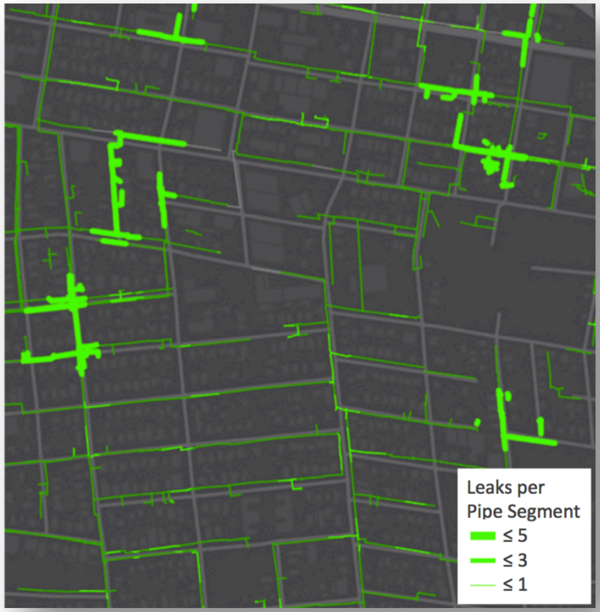
Statement of the Problem…

- How can we optimize our pipe replacement program:
  - To maximize removal of risk across all threat types?
  - To maximize leak removal using capital dollars?
  - Within budget & planned mileage?
  - Be as capital efficient with pipe replacement dollars as possible?

I can only replace one of these pipe sections this year… all other things being equal, I'd chose to retire the most leaks…

What if I knew *exactly* where *all* my leaks were?



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Limitations to "perfect" pipeline replacement choices

- DIMP models are just models and may not accurately describe the *actual* state of my infrastructure
- Even if my DIMP model *includes* leak data, leaks are dynamic
- I don't know where all my leaks are (and I have many more than I think I do)
  - Traditional leak survey only finds ~40% of my leaks
    - …and that data may be up to 3-5 years old
  - Ok fine, but if I'm using Advanced Leak Survey, *that* finds ~90% of my leaks!
    - …but... *that* data may be up to 3-5 years old too!
  - Leak creation rate on legacy pipe is nonlinear (it increases as the pipe ages) so I have more leaks than I think I do…

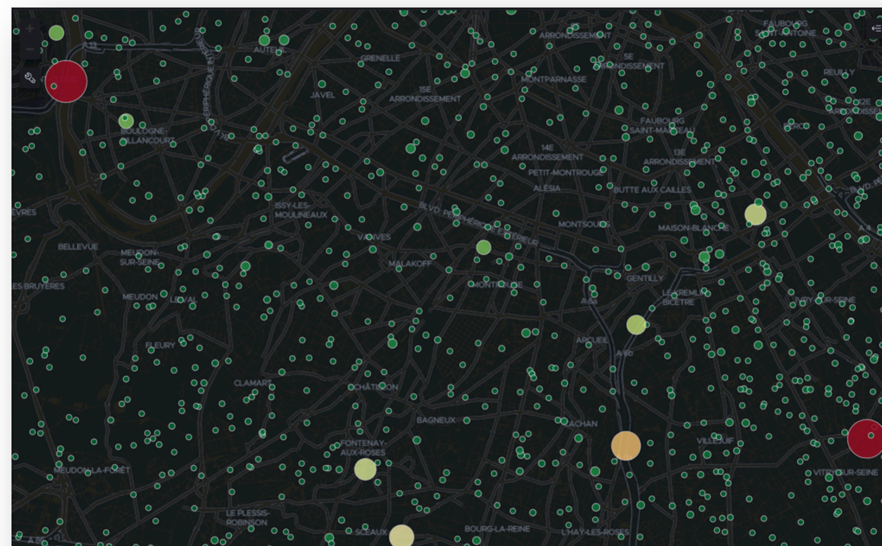
- I need a "real time" snapshot of the state of my highest-risk pipe…

- Methane emissions measurements can help…

Picarro's Hardware-Enabled Data Analytics

- Advances in mobile leak detection technology allow natural gas emissions data to be collected at a speed and scale not previously possible
- Advances in "Big Data" Analytics allow better-informed conclusions to be drawn from that data and action taken
- This data can be collected once and used for multiple use cases including Leak Survey, Risk Reduction (DIMP) & Emission Reduction

Emissions Data Collection

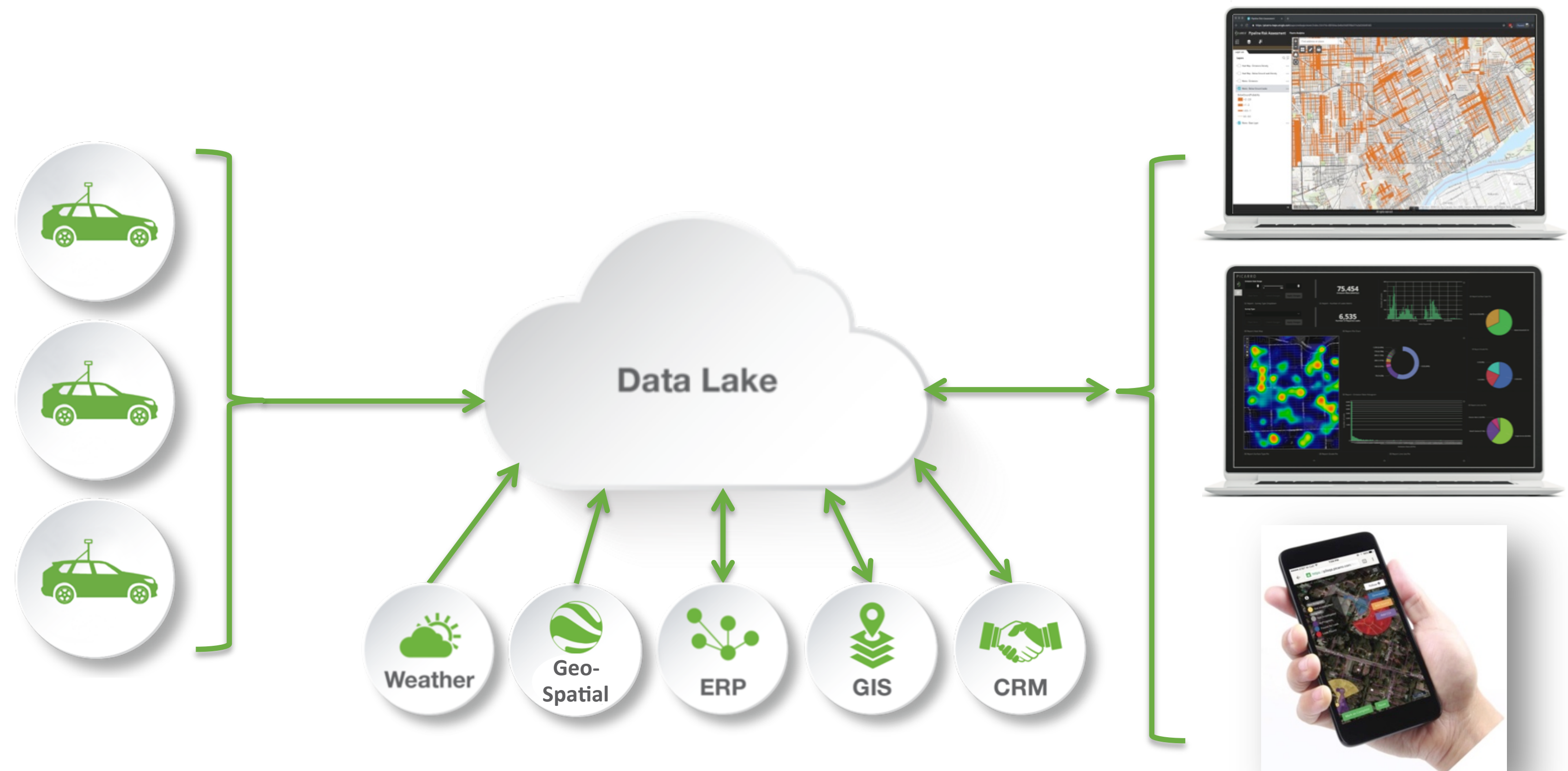


Emissions Data Management, Analytics, Visualization & Reporting

Picarro's Natural Gas Network Management Solution

Data collected once...

...used for multiple applications to deliver operational value



Data Collected by Picarro Hardware

Data Management,
Utility & External Data Inputs,
Utility Data Systems Connectivity

Reporting, Geospatial Applications
& Visualization & Actionable
Intelligence from Analytics

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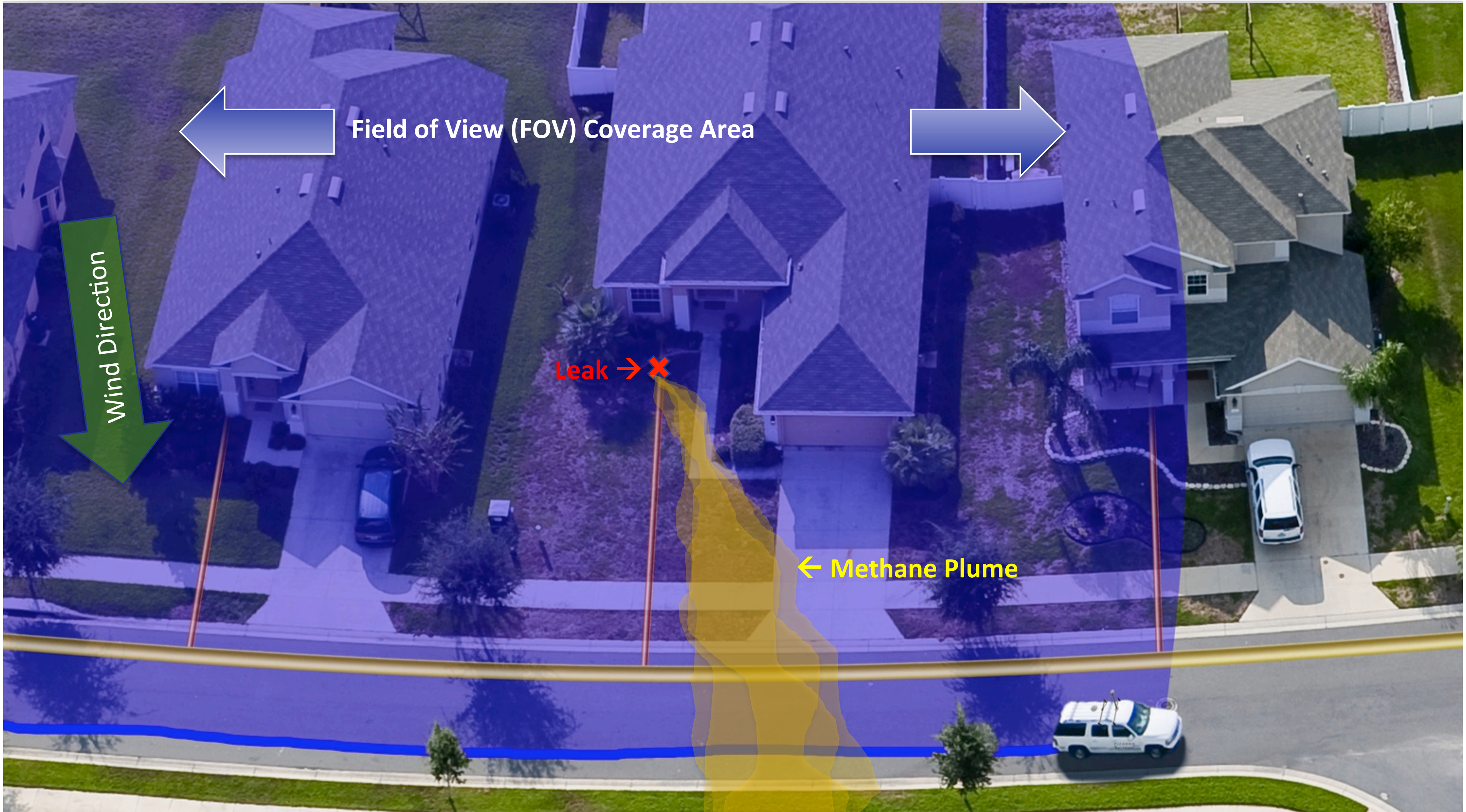
Advanced Emissions Measurement Technique

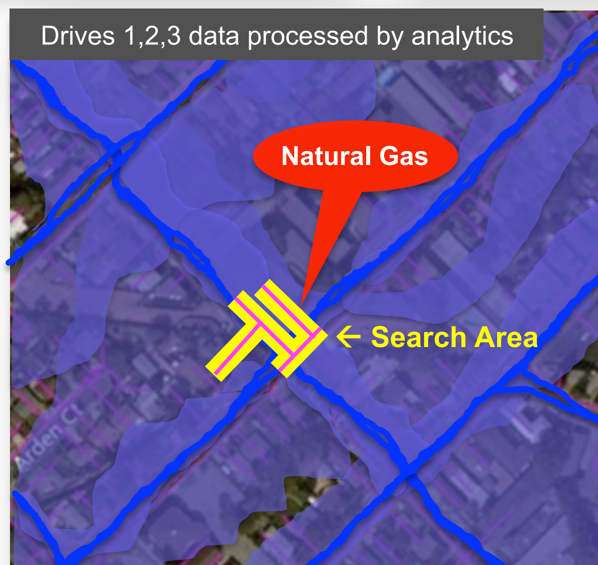


US Patents covering Picarro's software, data analytics & hardware specific to natural gas applications including FOV & search area concept patents:
14 issued: 9,719,879 9,645,039 B1 9,696,245 9,618,417 9,606,029 9,599,597 9,599,529 9,557,240 9,500,556 9,482,591 9,470,517 9,322,735 9,310,346 9,274,031 10,401,341 10,386,258 10,337,946 10,330,555 10,161,825 10,126,200 10,113,997 9,823,231 9,739,758

Data from multiple drives is processed by analytics to compute emission location, coverage & source attribution

Data from **multiple drives** combined and processed by **Analytics** to determine:

- Search Areas
- Source Attribution
- Field of View Coverage



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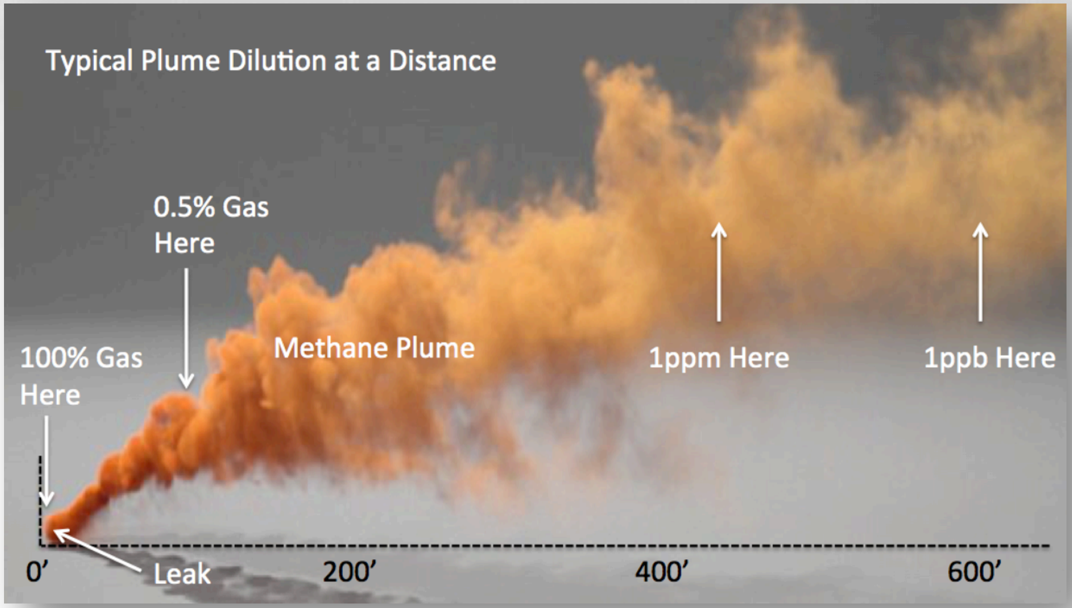
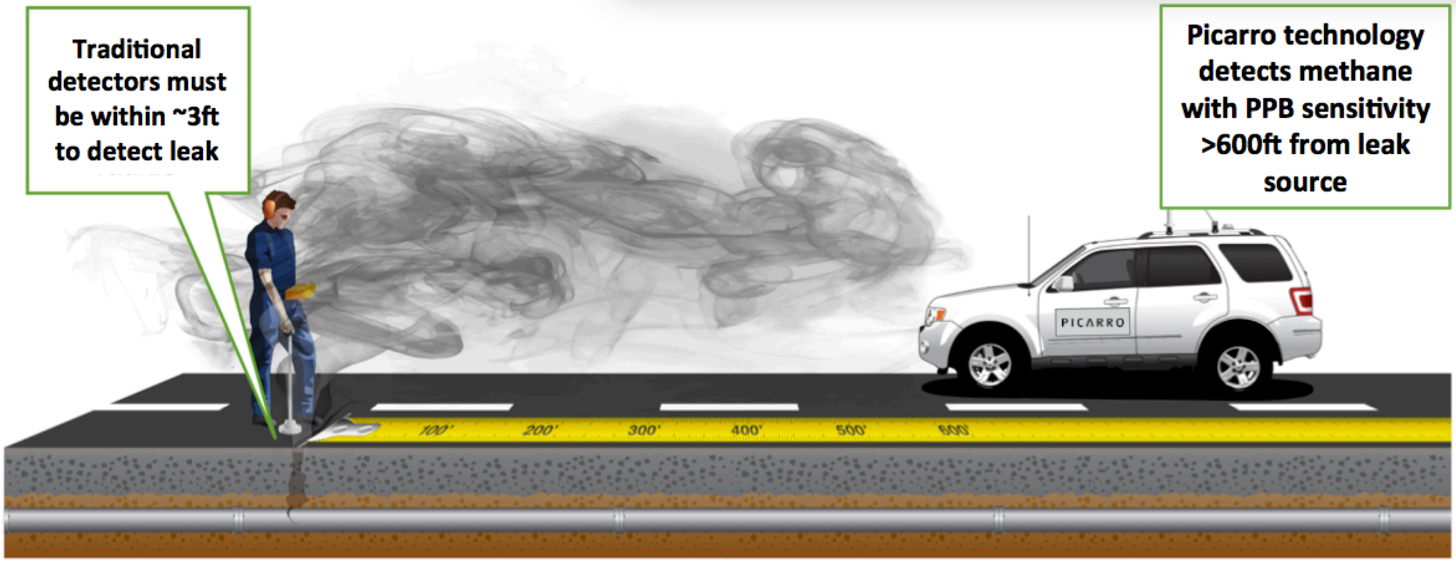
Detecting distant leaks

- Traditional leak survey equipment has PPM methane sensitivity & requires the detector to be within ~3ft to detect the leak because the gas dilutes quickly in the atmosphere
- Picarro detects leaks at a larger distance (>600ft) which requires very high PPB methane sensitivity and wind direction measurements to find the leak location





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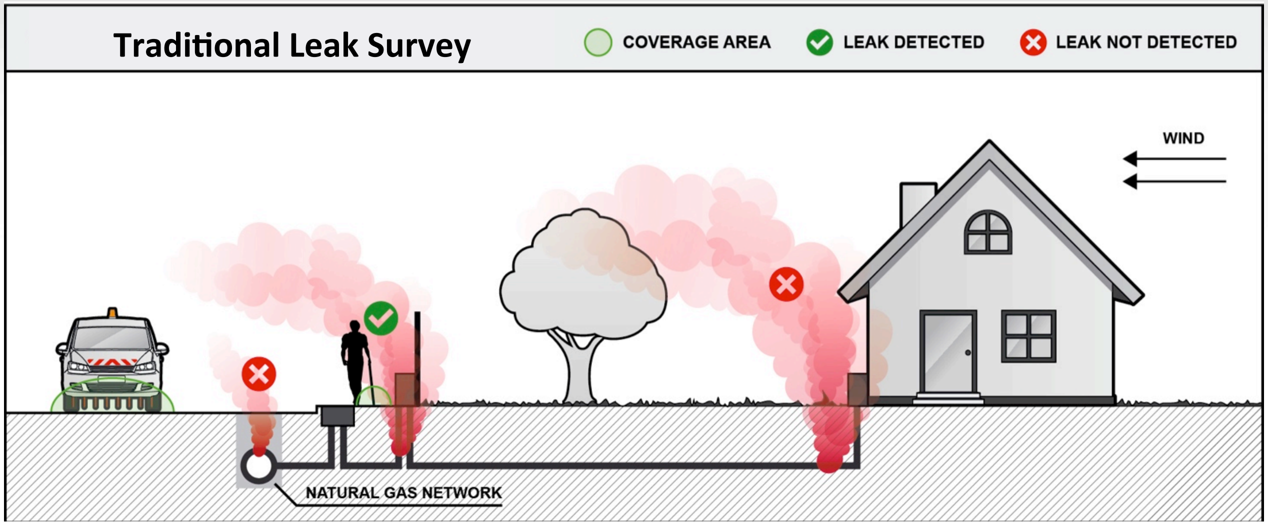
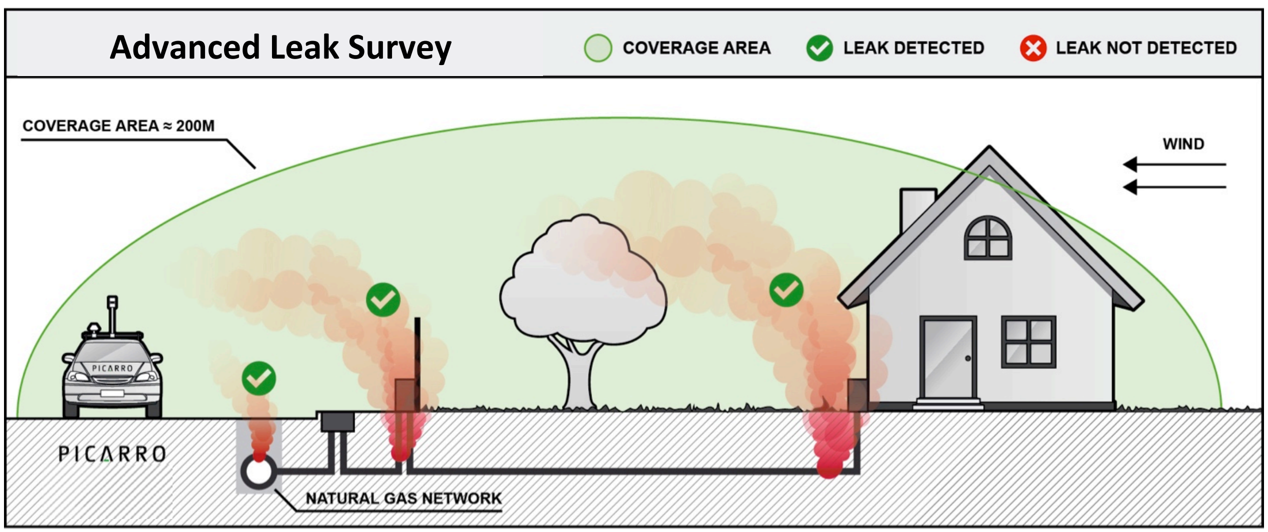
Advanced Leak Detection compared to traditional walking and mobile survey



Disadvantages:

- Only PPM sensitivity
- **Only detects ~32% of hazardous leaks**
- Limited coverage: must be directly over pipelines
- Detects only methane
- Depends on skill of technician
- Cannot use in rain/snow
- Slow walking & driving speeds



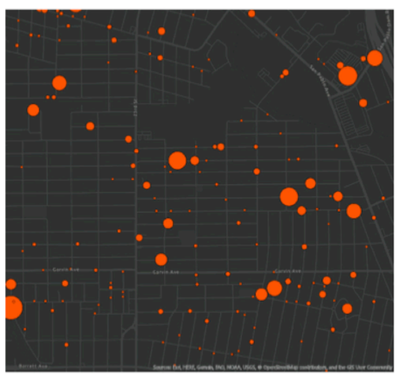
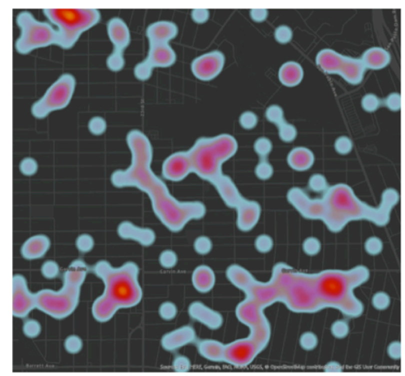
Advantages:

- PPB sensitivity
- Large coverage area
- **Detects ~91% of hazardous leaks**
- Detects methane & ethane: discriminates natural gas from sewer gas
- Not influenced by human error
- Detects leaks on the entire network (mains, services & meters)
- Can use in rain/snow
- Can drive at high speeds

Using methane data for applications beyond leak survey

- Measuring methane data provides a "live" snapshot of the current condition of pipelines
- There are qualities of methane plumes (shape/size/flow rate) that we can measure that correlate to the risk, size and type (i.e. belowground) of the leak that created the plume
- Using Picarro methane data and analytics, leak density and emissions are measured along pipe segments
- Depending on the goal, the methane data may or may not be used used to identify individual leaks as in the leak survey application

Fit-for-purpose analytics & visualizations of emissions data collected in an area

Analytical Model	Individual Emitters	Emissions by Pipe Segment	Emissions Heatmap
Visualization			
Application	Remediate Super Emitters	Pipe Replacement Optimization	Risk Mapping, Forecasting

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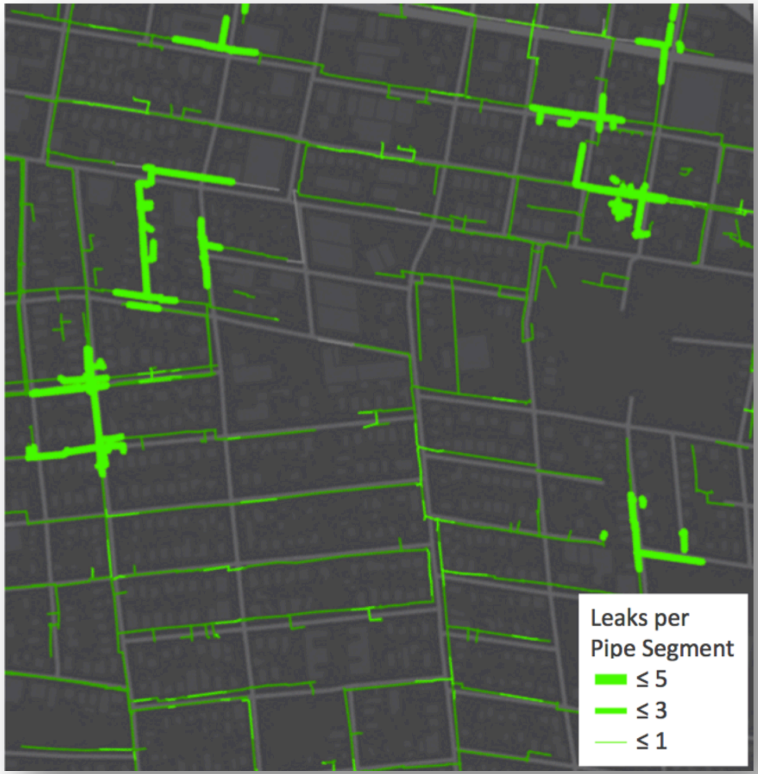
Emissions quantification & estimation of leak density

- Using methane data, analytics estimate leak density and measure emissions of pipe segments rather than identifying individual leaks
- Significant O&M (2-3x) cost avoidance by identifying pipe segments with highest leak density for capital replacement
- Better informs targeted emissions & risk reduction (DIMP) programs



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Pipe replacement optimization enabled by Picarro's emissions quantification & analytics

- Pipeline GIS merged with Picarro emissions quantification outputs
- Picarro uses collected emissions data to calculate estimated belowground leak density & emissions, aggregated over areas or along pipe sections

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Case Study: 276-mile distribution system in Northeastern US

- **Picarro Pipeline Replacement Optimization Case Study**:
  - 276-mile distribution system in Northeastern U.S.
  - Remediates 2x more leaks by complementing existing pipeline prioritization processes AND achieve $1M in O&M expense avoidance *annually* over the 90 miles replaced
  - The pipe replacement program identified 10 miles of main to be replaced in 2020.
  - Picarro measurements estimate they contain 28 below-ground leaks.
  - Picarro optimization identified 10 (different) miles of main containing 57 below-ground leaks (2x) at $3500 per leak repair

Picarro Emissions Heat Map of System in Case Study

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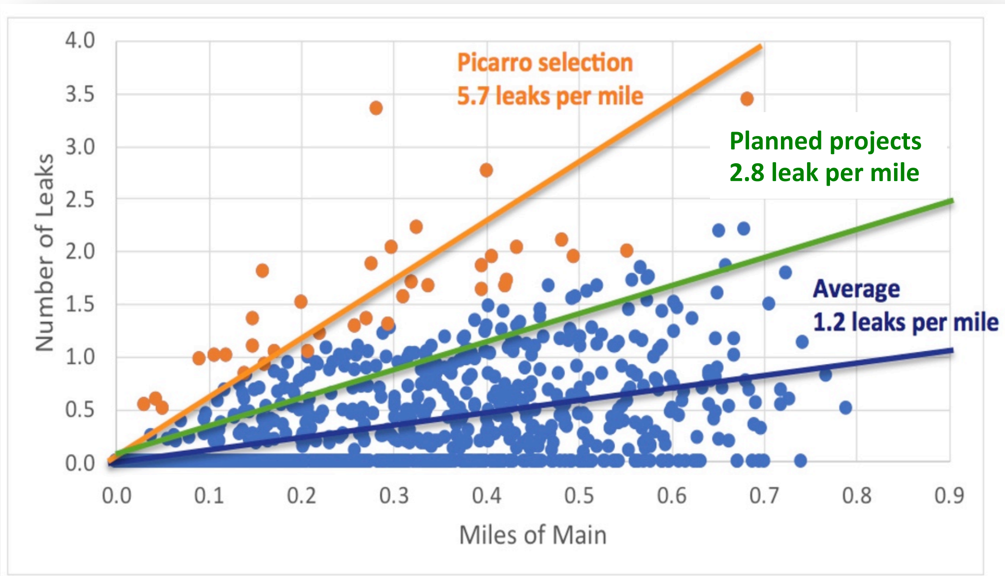
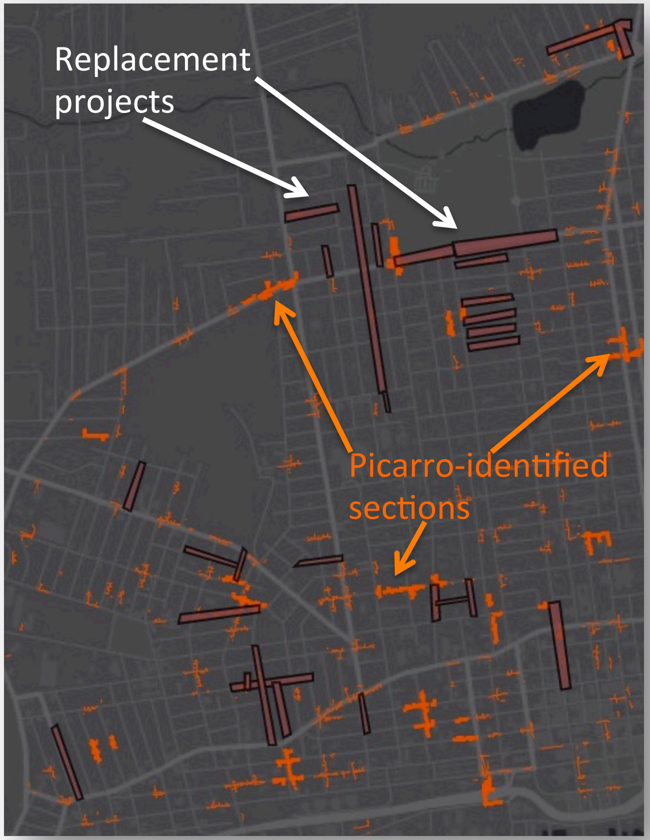
Pipeline Replacement Analysis Summary

By making *slight* changes to the planned replacement projects, the number of leaks remediated (and repair cost avoided) by pipe replacement can be increased by 2x

Picarro predicted leaks/mile in grids of 0.01sq mi



Picarro optimization would remediate 2x more leaks per mile as compared to the existing replacement strategy (5.7/2.8 leaks per mile = 2x)



5% overlap between Picarro leak density assessment and proposed 2020 replacement projects

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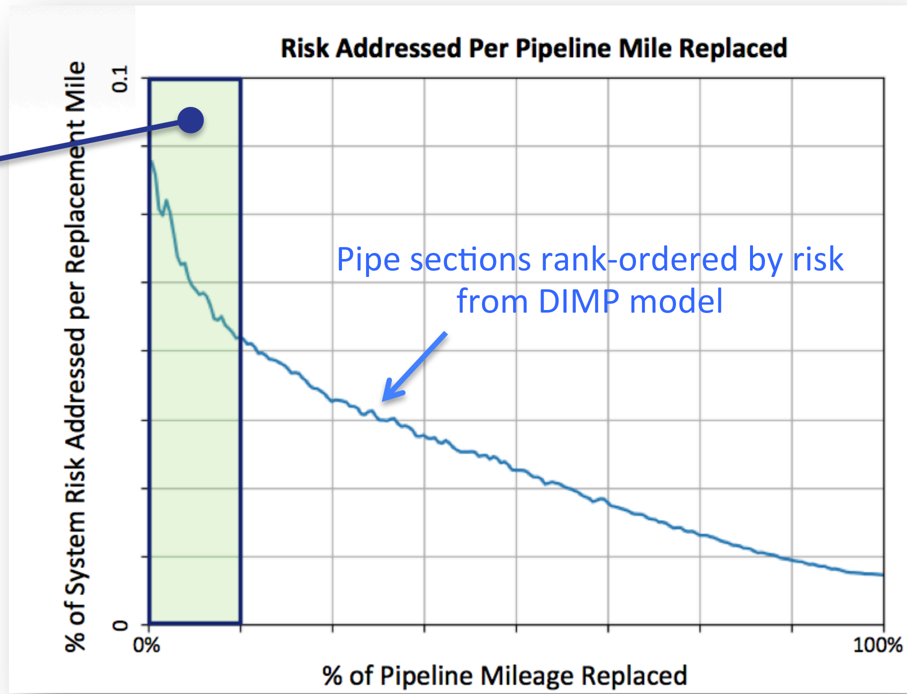
Example: Selecting Areas for Picarro Emissions Data Collection

- **Requirement:** retire at least as much total system risk annually with my DIMP program
- Assume 20k miles of distribution, replacing 1% of network annually (200 mi)
- Use DIMP model to rank-order pipe sections by RoF (risk of failure)
- On average, a 200-mi bundle selected randomly from a 2500-mi subset will address 1% of system risk (defined by the DIMP model), consistent with the current replacement scenario, meeting the requirement
- **Recommendation:** Collect emissions data on top 2500 mi of highest RoF pipelines in the network (12.5% of the network or 12.5x the replacement mileage)
- Define replacement projects from subset (200 mi) of pipe with highest leak density from the 2500-mi sample
- This addresses the same 1% of system risk from DIMP (or potentially *more than 1%*), *and* removes more leaks at the same time

2500-mi subset:

- Collect emissions data on it
- Select 200 miles to replace that have highest leak density



Picarro Pipeline Replacement Optimization Process Diagram

Network Risk Analysis and Planning

- Analyze network risk based on DIMP outputs (RoF, CoF, LoF)
- Define high-RoF replacement candidates for (ideally at least 10x the miles that can be replaced each year)

Picarro Optimization

- Drive Picarro & collect emissions data on high-RoF pipelines defined in network analysis and planning exercise
- Run Picarro algorithms to produce GIS outputs (heatmaps, aggregations of emissions and leak estimates on pipelines and boundaries)
- Define replacement bundles based on ranking the high-RoF pipelines by the estimated number of leaks

Project Scoping and Benefit Analysis

- Scope replacement projects using exiting criteria, prioritizing from bundles with the largest number of existing leaks
- Evaluate O&M savings compared to existing or average replacement scenario

Summary of U.S. Case Study Results of Picarro Pipeline Replacement Optimization

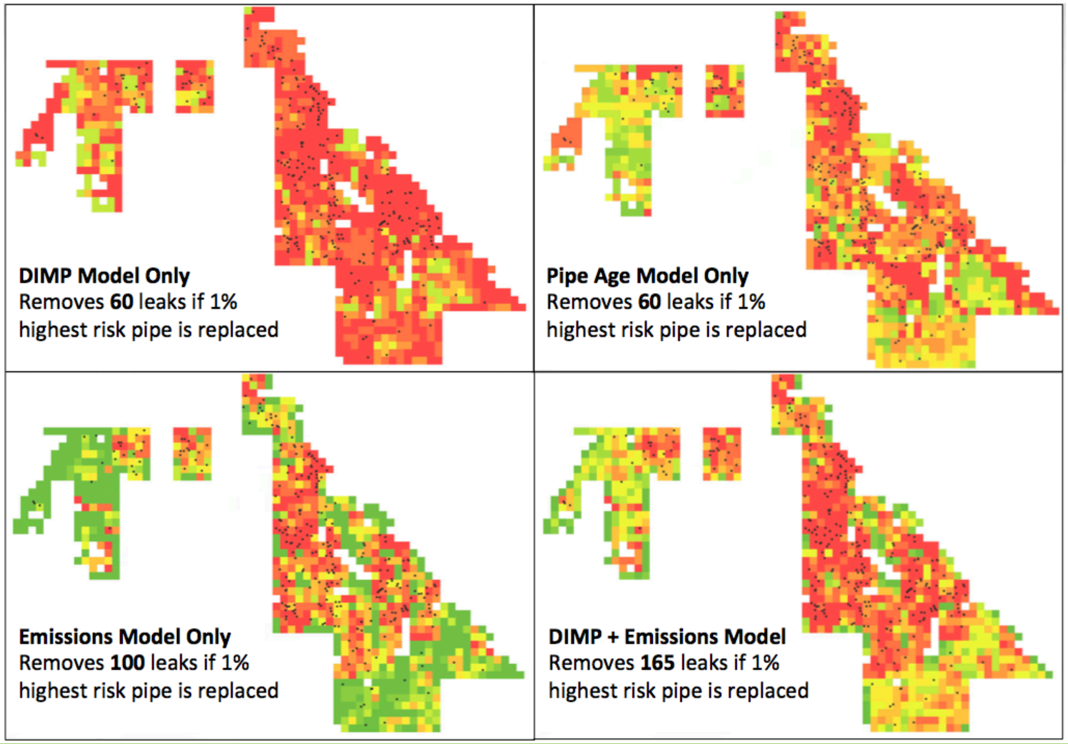
- Use Picarro emissions quantification data to augment DIMP models and optimize pipe replacement programs
- Replacement mileage remains as planned, but *different* projects are selected in upcoming year to maximize leaks removed by pipe replacement
  - Cost savings is through avoided leak repair cost if leaks are found before pipe is replaced
  - Maximizes risk reduction per pipe replacement dollar
  - Maximizes emissions reduction
- Picarro emissions data collected at multiple utilities shows ~$1M+ annual cost savings potential through DIMP model optimization using Picarro

U.S. Case Study Utility Location	Below-Ground Leak Repair Cost	Picarro DIMP Leak Removal Multiplier	Annual Pipe Replacement Mileage	Leak Repair Cost Avoidance per Replacement Mile Using Picarro Optimization	Total Annual Leak Repair Cost Avoidance Using Picarro Optimization
Western U.S.	~$7k	2.75x	~200	$6.2k/mi	**$1.25M**
Southern U.S.	~3.5k	1.5x	~200	$4.6k/mi	**$910k**
Northeastern U.S.	~$3.5k	2x	~90	$10.2k/mi	**$914k**
Midwestern U.S.	$5k	3.5x	~70	$14k/mi	**$980**

Things we've learned…

- Example ideal replacement scenario at one utility where the highest-risk 12% of the network (ranked by the estimated number of leaks using emissions data) was binned into replacement increments:
  - Ranking by the number of predicted leaks did not impact the type of threats addressed
  - Most of the highest-leak-density pipes were within the top ~25% replacement segment bins
  - 75% of the replacement segment bins had few or zero predicted leaks
- There is good overlap between which pipe sections have high predicted leak density using methane data and which have high risk predicted by the DIMP models

- Emissions is a better predictor of LoF than Pipe Age only or even the full DIMP model (where age and material type usually drive LoF). Considering Emissions + DIMP is the best predictor of LoF. →
- If emissions is used in DIMP model, it should have weighting similar to or higher than pipe age and material



Thank You!