DPFs—Is There An Ultrafine Problem? CATF's Investigations and Response.

L. Bruce Hill Ph.D., Senior Scientist

Clean Air Task Force, Boston MA

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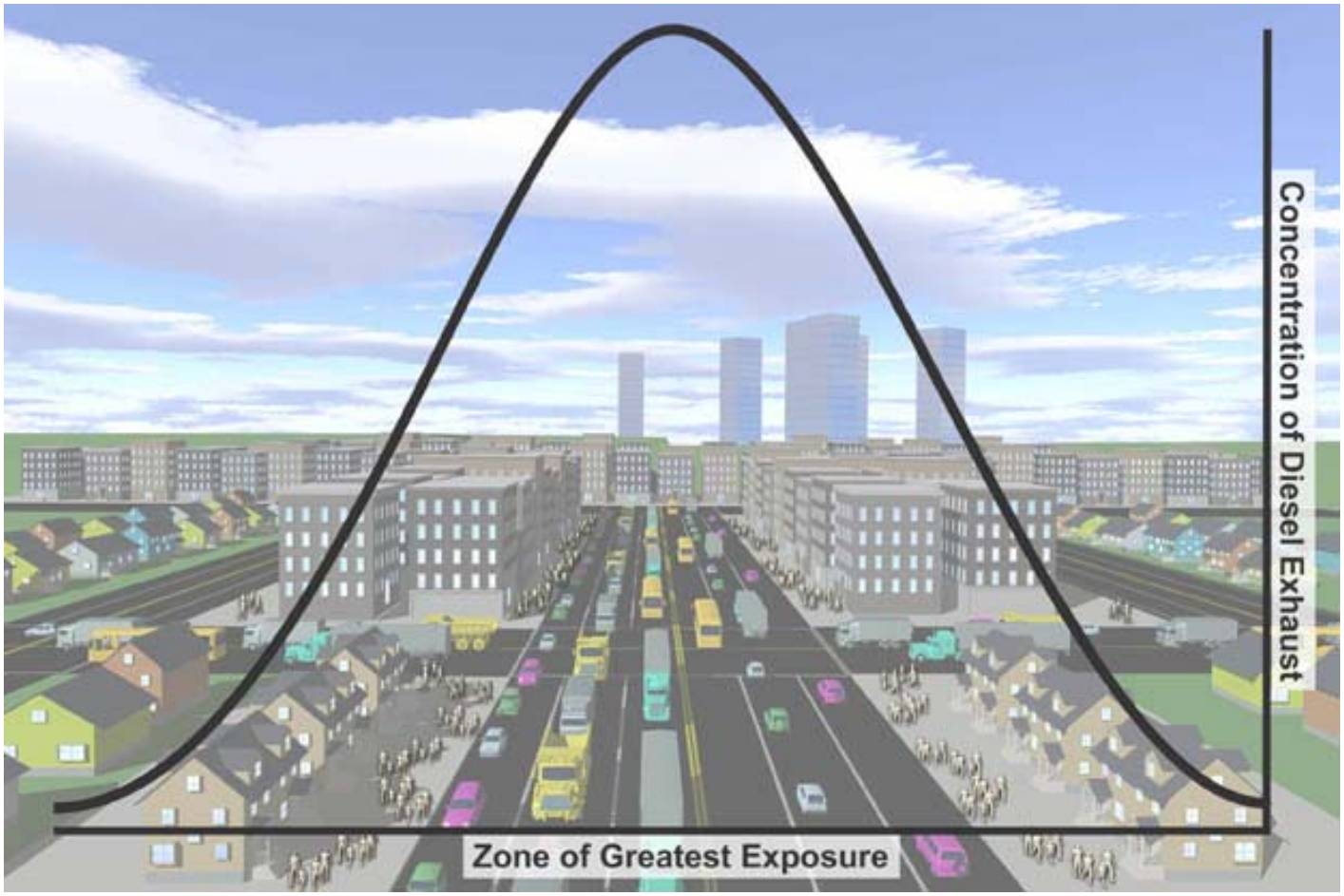
At Issue: Are DPFs unintentionally <u>increasing</u> nanoparticles/UFPs along roadways?
A Quick Review of Recent Assertions



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In the lab: Secondary [sulfate] Ultrafine Peak <50 nm
Some studies show tail down to 5 nm.

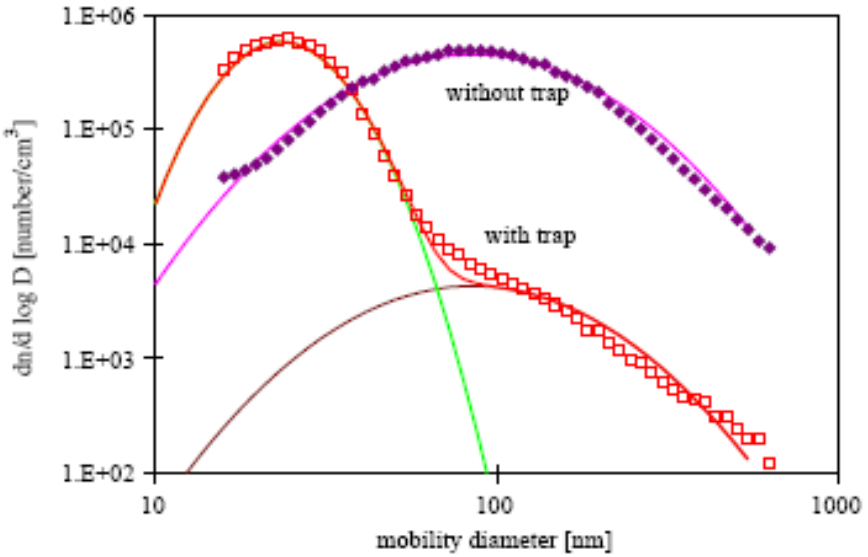

Fig. 4. Typical size distributions of diesel exhaust particles emitted from a heavy-duty engine equipped with a particle trap (results with and without trap are shown). Without trap most particles are in the size range of 30–300 nm (accumulation mode). After the trap the concentration of the accumulation mode particles is reduced by about two orders of magnitude. However, a large number of particles occur in the nucleation mode. They dominate the particle number. Without trap volatile material condenses on the solid particles. As the trap removes the solid fraction no surface to condense on is available. The resulting higher supersaturation leads to homogeneous nucleation of the volatile material, passing the trap in the gas phase. This means that even if the concentration of ultra-fine particles is higher after the trap than before, no new material is created. It just occurs at a smaller size. Experiments show that most of the newly formed nucleation particles do not have a solid core. They can be completely evaporated or dissolved. This will also happen after precipitation in the respiratory tract. Therefore, it has to be assumed that the health effects of these particles will be completely different from solid particles. Both modes can well be approximated by lognormal distributions (solid lines are lognormal fits to the measured data).

Response Depends on DPF.
Ex: Kittleson, 2006 CRT vs CCRT:

Table 3
Average daily particle concentrations by sample source and control device

Date	Source	Control	N[a]	SMPS N	SMPS, part/cm^3		EEPS, part/cm^3		CPC, part/cm^3	
					Avg	SDOM[b]	Avg	SDOM	Avg	SDOM
7/27/2004	Background		5730	53	1.01E + 04	1.13E + 03	4.90E + 04	1.06E + 03	4.51E + 04	9.13E + 02
7/27/2004	Plume	CRT	5182	48	1.50E + 05	7.79E + 04	1.24E + 06	3.74E + 04	1.46E + 06	3.48E + 04
7/29/2004	Background		5580	50	1.86E + 04	1.83E + 03	1.25E + 05	2.25E + 03	9.19E + 04	1.62E + 03
7/29/2004	Plume	CRT	4963	44	2.79E + 04	3.84E + 03	6.55E + 05	2.17E + 04	7.68E + 05	1.94E + 04
8/5/2004	Background		5924	54	1.43E + 04	4.47E + 03	8.33E + 04	2.19E + 03	5.14E + 04	1.32E + 03
8/5/2004	Plume	CCRT	5272	48	1.07E + 04	1.81E + 03	8.37E + 04	2.01E + 03	4.83E + 04	1.06E + 03
8/11/2004	Background		3980	34	1.62E + 04	4.16E + 03	1.12E + 05	2.66E + 03	1.08E + 05	2.54E + 03
8/11/2004	Plume	CCRT	3290	30	1.70E + 04	6.43E + 03	7.44E + 04	2.49E + 03	7.20E + 04	2.22E + 03
8/12/2004	Background		6134	54	9.52E + 03	1.74E + 03	5.56E + 04	1.03E + 03	6.74E + 04	1.13E + 03
8/12/2004	Plume	CCRT	5274	48	7.74E + 03	1.30E + 03	5.13E + 04	9.52E + 02	5.82E + 04	1.01E + 03

[a] N is the number of measurements recorded by the data logger at approximately 1 s intervals.
[b] SDOM is standard deviation of the mean.

Note: CCRT may become saturated and perform as CRT.

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What We have learned about DPFs and Emissions

- Secondary nanoparticles formed are sulfates. (ES&T Kittleson paper, July 2006).
- UFPs disperse locally. Zhu, 2002, others, suggest within ~100m of roadway.
- The nucleation-mode UFPs disperse rapidly and form accumulation-mode fine particles.
- Sulfate nanoparticles are a result of fuel S content: ULSD 15ppm fuel, nearly eliminating S reduces problem.
- Sulfur in the engine oil can also result in secondary sulfate nucleation.
- High engine temperatures are required to convert the engine out SO2 to SO3. Kittleson has found a 'critical' engine temperature of ~325C for nucleation to occur.
- Cauda et al, (ES&T 2006) suggests that UFPs formation can be resolved by performing a mild regeneration at lower temperatures

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UFP Research Indeed Suggests Health Risk but Weight Does not Rival FPs.

- Since late 1990s, a variety of significant papers suggest associated health risk ranging from respiratory to cardio morbidity including DNA effects and penetration into bloodstream. Mortality linked to UFPs in Peters, Dockery Ehrfurt Germany study.
- However, Dockery's hypothesis is that UFPs and PM2.5 behave similarly in the lung—PM2.5 breaks down into constituent UFPs. (Pers commun 8-29-06)
- UFP lit is relatively small at this time—credible but perhaps --taken together-- yet to be fully robust, unlike the statistical power of the PM cohort studies and the 1,000s of fine particle epi studies.
- Weight of evidence supports FP damages for adults and children across all major cities (e.g. see ACS, 6 Cities, NMMAPS, NAAQS CD and many other studies).

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Eye on the Target.
Health Research Still Points to *Fine Particles* (>100-1000 nm).

- ****UFPs and FPs poorly correlated** The FP effect across 150 metro areas in the US (e.g. ACS, 6 Cities, NMMAPS as well as international studies) *cannot be explained by UFPs* as a 'smoking gun'—this means that PM2.5 is still prime reduction target.**
- **There is no debate that DPFs remove 90+% of soot particle mass. If the organics have condensed onto the soot prior to the trap they will be removed also.**
- **The particles of greatest concern may be the 200 nm particles—the size mode with the highest surface area for adsorption of toxics. These are larger than nanoparticles and are removed by the DPF with the accumulation-mode particles.**
- **DPFs indeed remove the toxic fraction; bioassays are less toxic to lab animals (McDonald, 2004)**

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Also..Do DPFs cause an enhanced NOx problem?

- Typical 4-stroke diesel exhaust contains about 95% NO and 5% NO2.
- The DOC section of a CRT converts some of the NO to NO2 (25% to 40%) and uses this to oxidize carbon (so some NO2 returns to the NO state and some actually reduces all the way to N2).
- The net result is about a 5% decrease
- Emissions are proportionally about 80% NO and 20% NO2.
- The total NOx (by mass) actually goes down .

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CATF Video Chase Studies

Nanoparticle/UFP Emissions Behind Conventional and DPF Retrofit Transit School Buses & Sanitation Trucks on Ann Arbor, Boston and NYC Streets

NOTE THIS IS LARGELY RECENTLY COLLECTED DRAFT DATA, SUBJECT TO CPC 3007 CORRECTION AND Q/A Q/C.

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Ann Arbor MI School Buses, 2004 (PTrak UFP Data Only)

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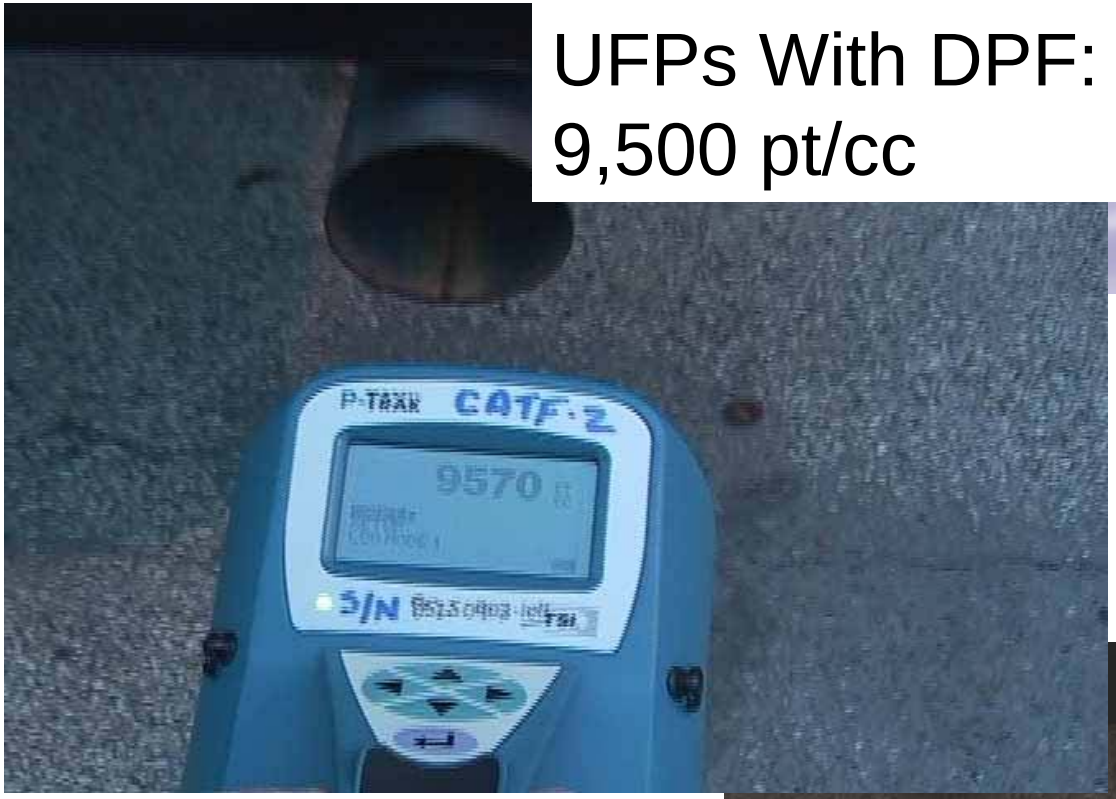
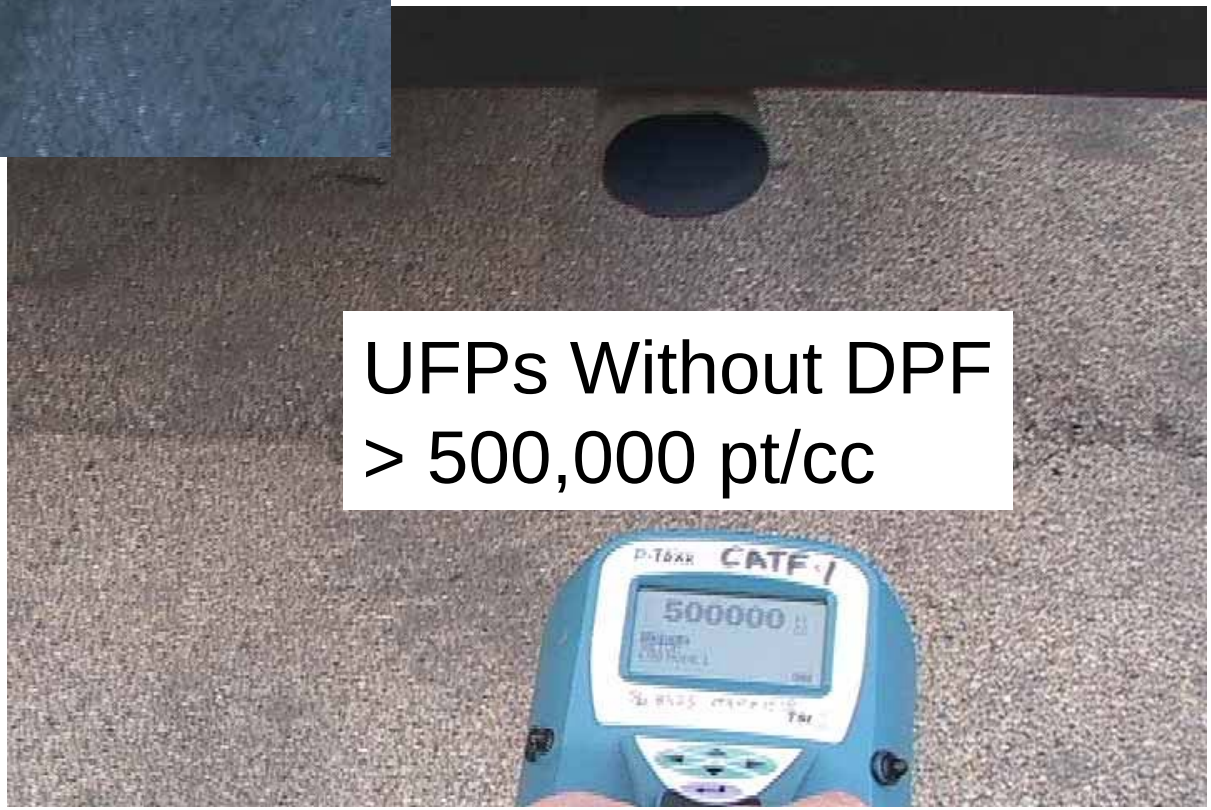


UFPs With DPF:
9,500 pt/cc

At School Bus Tailpipe
PTRAK: UFPs > 20nm



UFPs Without DPF
> 500,000 pt/cc

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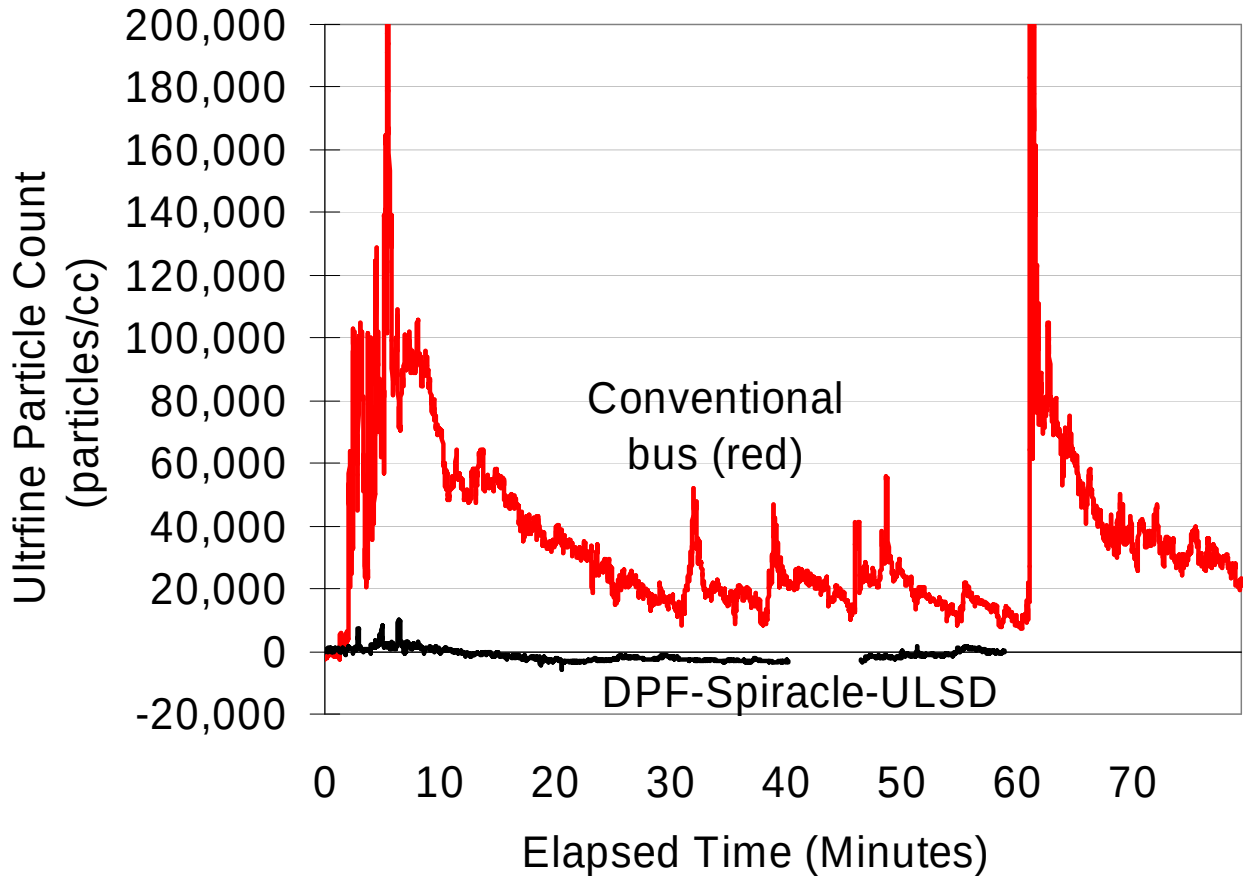
DPF reduces UFPs inside school buses (PTrak)



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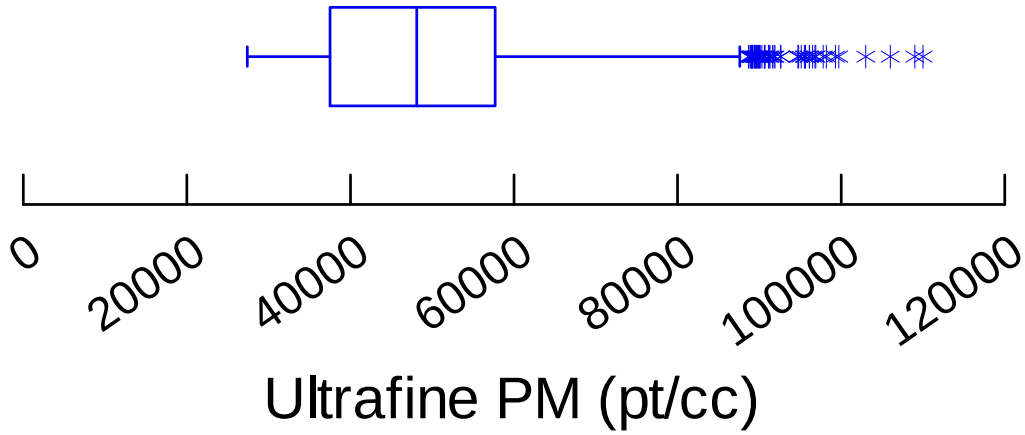
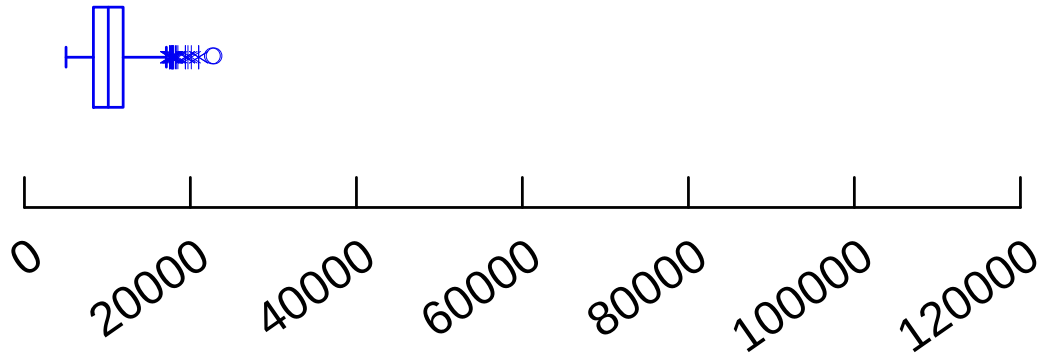
Boxplots of School Bus Cabin Air: UFPs reduced by DPF

Conventional Bus Atlanta



Retrofit Bus Atlanta



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PTrak Data UFPs >20 nm

School Bus Video
Ann Arbor MI in 2003

DPF virtually eliminates UFPs >20nm behind bus <u>& inside Bus</u>

(PTrak Data)

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Boston MBTA Buses
September 2006
CPC 3007 and PTrak Data

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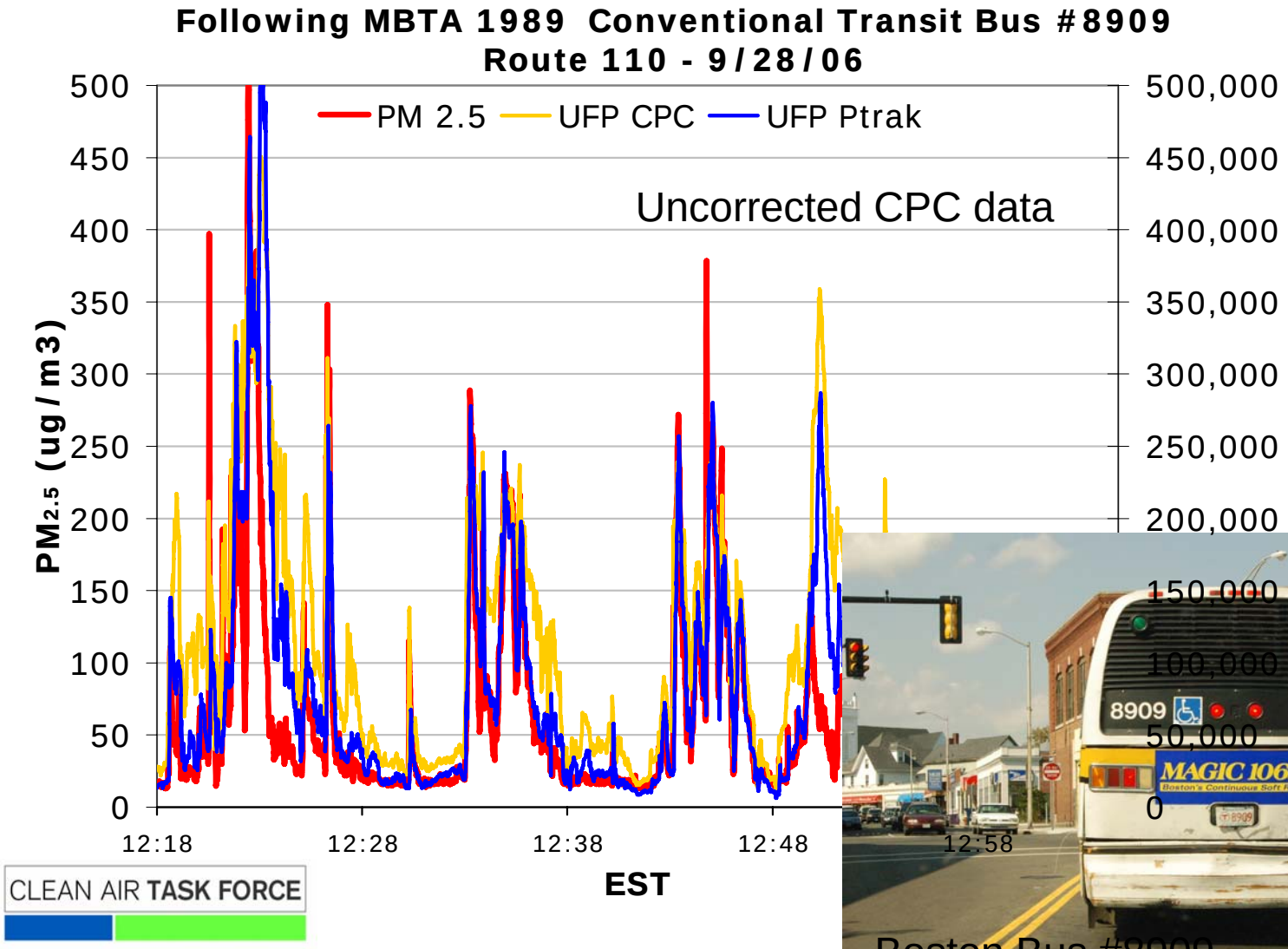
MBTA Conventional Transit Bus: High UFPs (PTrak & CPC 3007) and PM2.5 (Dust Trak)



Boston Bus #8909

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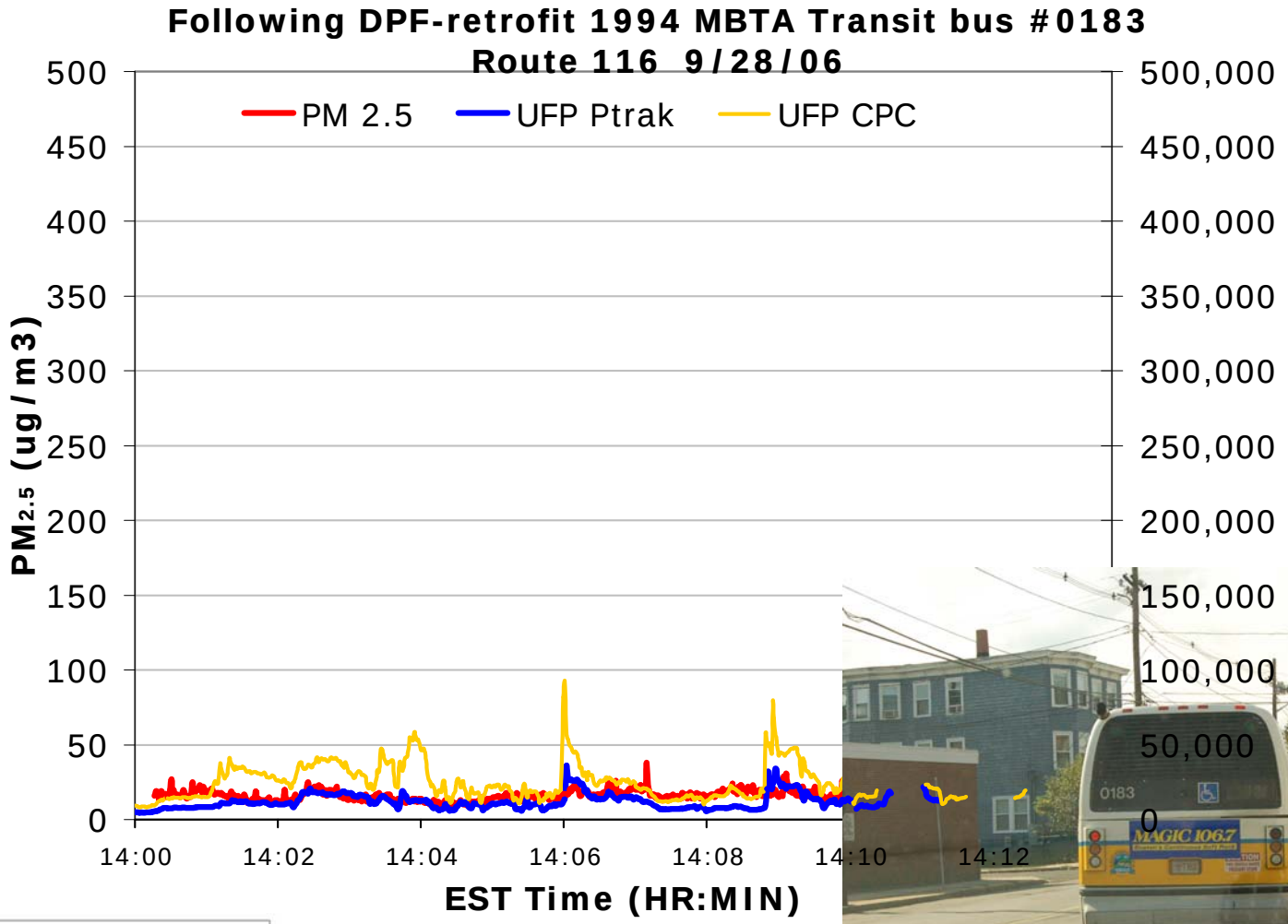
Boston MBTA 1994 CRT DPF-Equipped Transit Bus: UFPs and PM2.5 Reduced.



Boston Bus #0183

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New York Transit Buses and New York Sanitation Trucks
October 2006
(CPC 3007 UFP Data)

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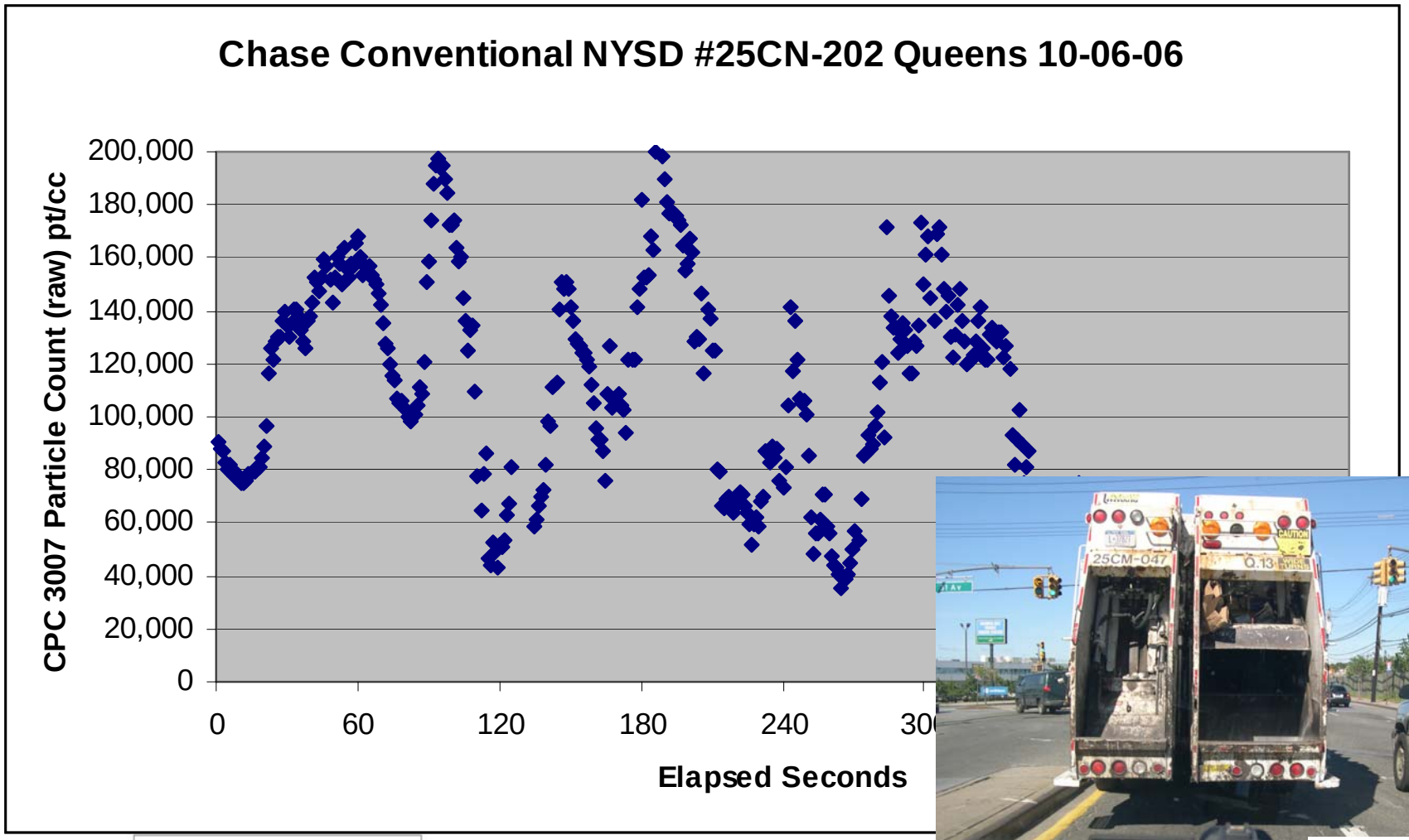
NYSD Conventional Sanitation Truck Queens, NY



Not the tested Truck.

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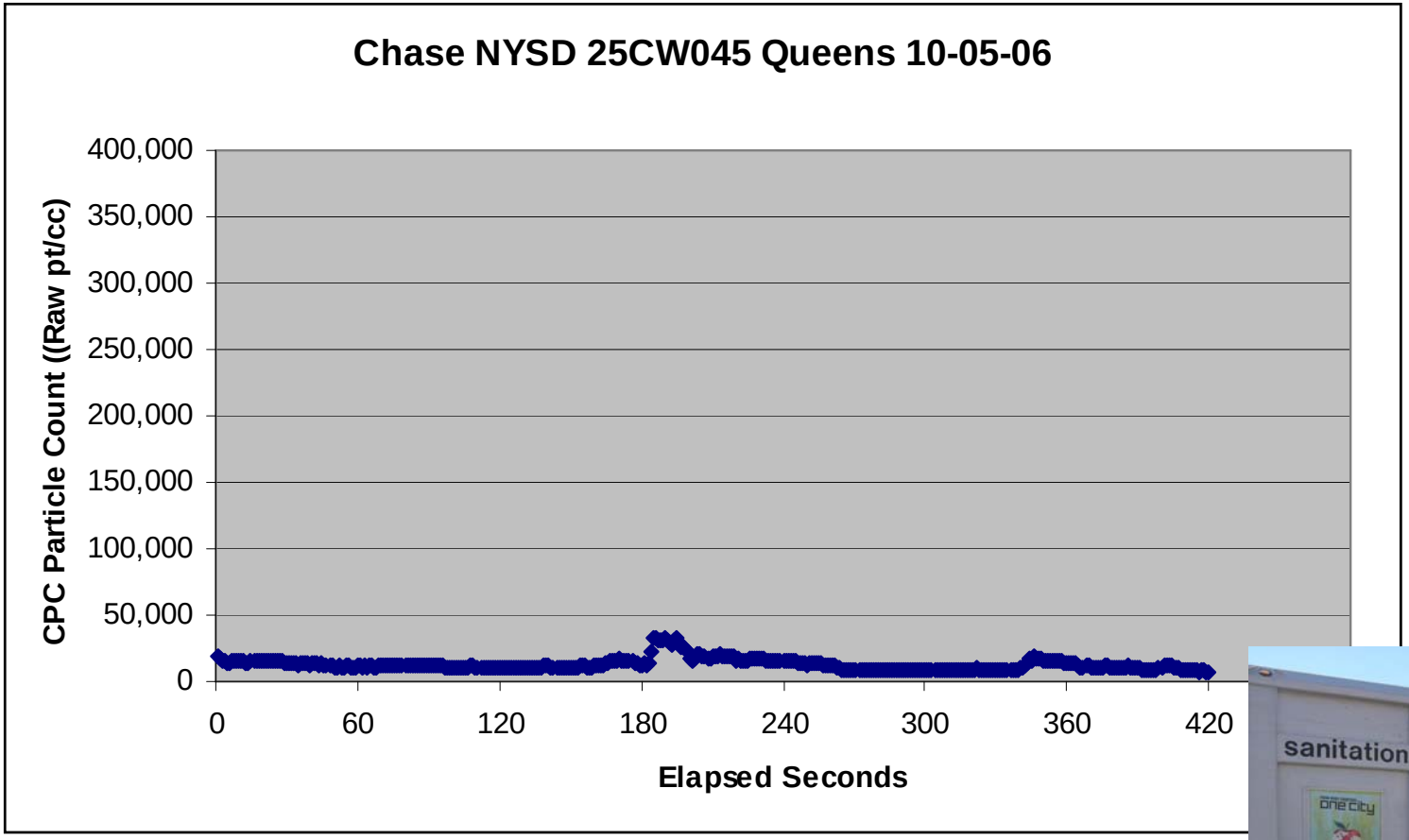
NYSD DPF Retrofit Sanitation Truck



Note: Raw Data; pre Q/A

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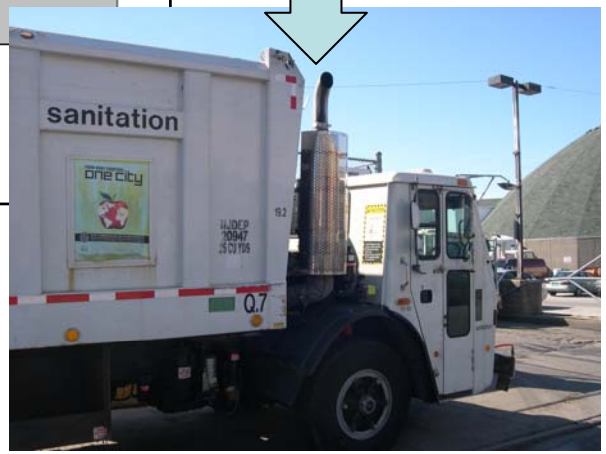
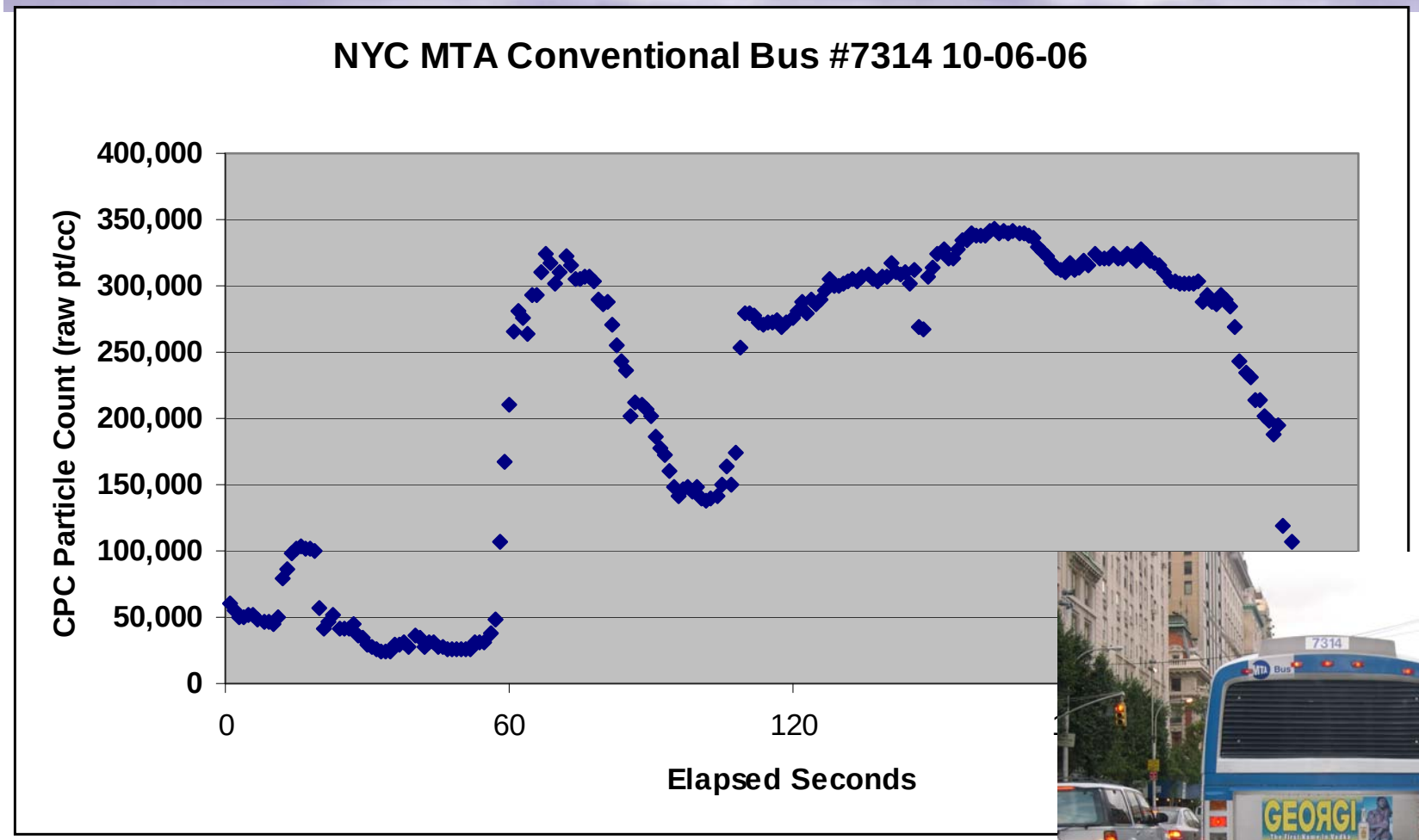
DPF



Not the tested Truck.

NY MTA Conventional Bus Chase



Bus #7314.

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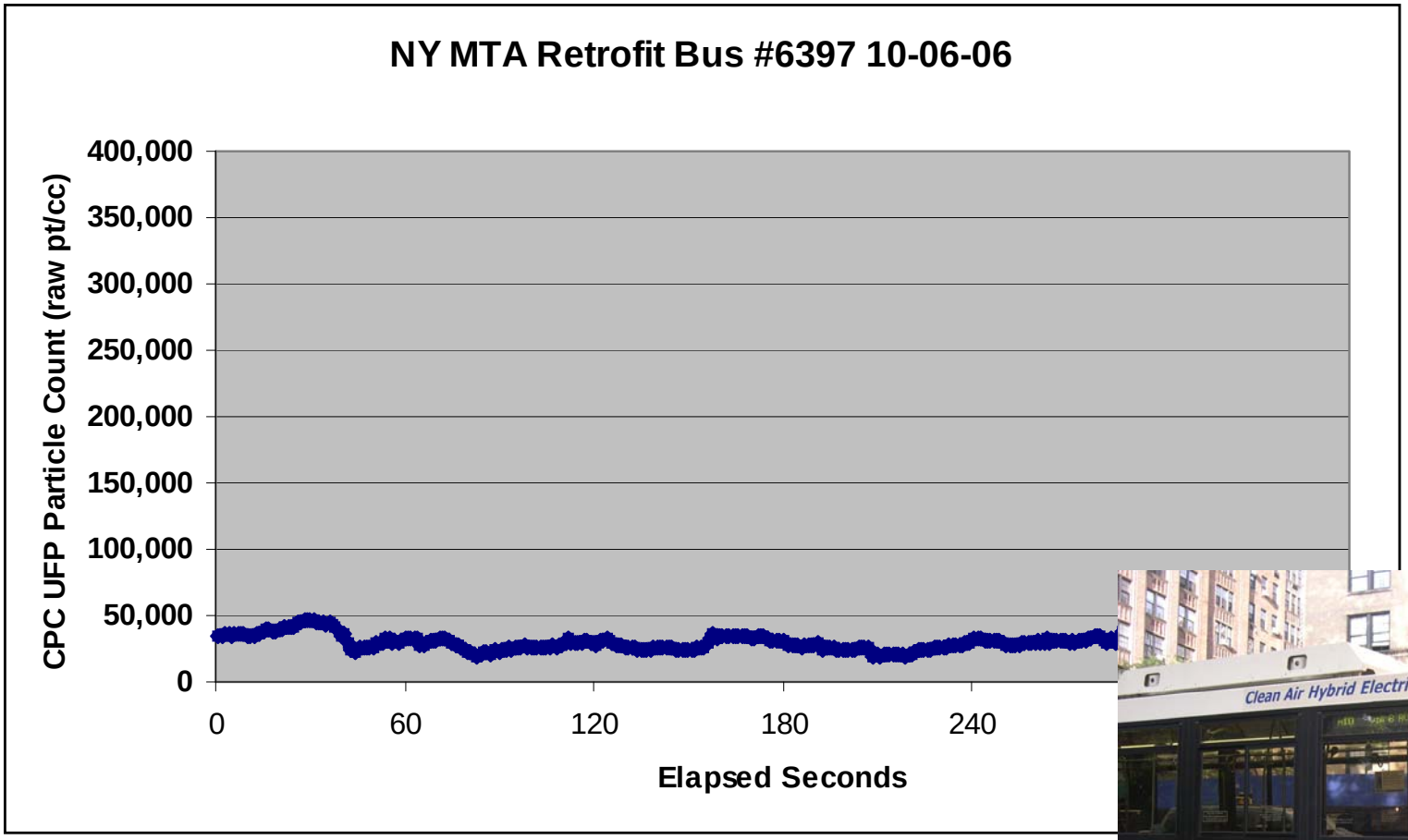
Chase NY MTA Retrofit Bus # 6397



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The Bottom Line.

- There are 13 million diesel engines in the US. Retrofits are an important solution.
- Our data suggest DPFs work extremely well.
- Even if imperfect under *some* conditions DPFs are the best technology to reduce local PM and UFPs.
- Alternatives DOCs, super DOCs, biodiesel, much higher PM and UFPs by orders of magnitude.
- There is no debate that DPFs remove 90%+ of PM mass. There is a robust link of PM mass with morbidity and mortality and mounting evidence of UFP health damages but scientists are not saying at this time that UFPs are the smoking gun in PM.
- To discourage DPFs , even in the worst case of UFP formation, (again, which we don't see on city streets) would be to throw the baby out with the bathwater.

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Contact Info

Bruce Hill

Senior Scientist

P.O. Box 815

Jackson, NH 03846

(603) 383 6400

bruce@catf.us

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