AAFEX Status Report #7 – 26 January 2009

Primary Activities: Area cleanup; last-minute plumbing checkout; shake-down engine run; engine exhaust mapping; downstream plume chemistry experiment.

Weather: 38 F at 7 am, dry with mostly clear skies and westerly winds right down the nose of the aircraft, perfect for sampling exhaust emissions at the 200-m trailer. Temperatures Warmed to near 50 F in the afternoon, then cooled to < 40 F after sunset.

Brief summaries of the days many activities:

- Robert and his team worked at a brisk pace and were able to finish all the last-minute leak- and functionality checking by around noon. Equipment covers and protective strapped were installed shortly afterward (Figure 1).

- Prem and Bruce worked to develop run sheets for the shakedown and exhaust mapping experiments; these were subsequently disseminated to science and aircraft crew and were used to establish engine power and sampling points during the tests (Figure 2).

- Anuj and the LaRC/UTRC and AFRL teams continued the black-carbon instrument inter-comparison that was begun on Sunday. The CAST was used to generate a wide range of soot particle sizes and concentrations, which were in turn sampled by MAAP, SMPS, TEOM, and photo-acoustic instruments in the LaRC and AFRL trailers. Although the measurements were in general harmony, results of the study suggest that differences in sample line characteristics (lengths, diameters) can lead to significantly different values of soot emission indices.

- A pre-test briefing was held at 1 pm in the building adjacent to the run site—over 50 people attended and were part of the subsequent test. A list of names was compiled and that will be included in a future report. Frank reviewed safety proceeds and briefed the team on what to do in case of a fire. Investigators were polled as to their readiness and all gave the thumbs up. When the meeting adjourned at 1:20, participants scurried to their trailers to prepare for the engine run.

- The "Shakedown" run began at 1:52 pm, with Mike and the Aircraft Operating Crew firing off the APU to provide bleed air for spinning up the engines. Dan Bulzan was test conductor and sat in the 4th seat in the DC-8 cockpit, right beside the flight engineer's station. Dan was in head-set communication with the AAFEX investigative team; his role was to relay requests and information between the science and aircraft crews and to record engine operating parameters such as N1, N2, EGT, and fuel flow. Bruce led the 1-m investigator team and directed sampling probe/engine run changes; Prem was the "score-keeper" in terms of monitoring time on point, directing valve-switching, etc.; Steve (Figure 3) worked the probe selection/ dilution flow system; Scott led the downstream team; and Robert stayed

outside to monitor the health of the sampling equipment. The #2 engine was fired up at 2 pm with the #3 following at 2:03 pm. Engine power was advanced at about 5-minute intervals starting at 4%, then 7%, 30%, 45%, 65%, 85%, and finally 100% of maximum RPM. Robert noted that the flexible sample lines connected to the 30-m inlets began to move around at the higher thrust settings, but that all other equipment remained steadfastly attached to the surface. After the run, the flexible lines were replaced with thick-walled, stainless tubing and additional concrete anchors were installed to reduce the possibility of movement.

- During the shakedown run, the 1-m aerosol team sampled from the 1-m rake tips as well as the 30-m inlets. Steve controlled the valve settings and dilution flow rates. Fluctuating particle concentrations were noted from some of the inlet tips (more on that below) and very high concentrations (>1e7/cm3, EIn>2e16/kg) were seen at the 30-m sampling positions. Changlie reported an SO2 EI of 2.5 g/kg, which suggests the fuel contains about 1250 ppm of sulfur contaminants; the downstream team reported seeing fairly significant amounts of sulfate aerosol in the diluted exhaust plume. AFRL noted that their gas-inlet probes on the #3 rake were not within the core flow as they were seeing very low CO2 values; the #3 rake, which was originally position 6” to the right of the engine center line, was translated to 2” off axis prior to the mapping test in an attempt to solve this problem.

- After modifying the 30-m sample lines (Figure 4) The Exhaust Mapping Test began at about 4 pm. The test matrix involved running the engine at 4, 7, 30, 45, 65, 85, and 100% power and collecting aerosol samples from two 1-m and 30-m inlets at each power setting. At 4, 30 and 65%, sample was alternately drawn from all 6 inlet tips on #3 rake and all 4 tips on the #2 rake to establish the “sweet” spot in the exhaust plume; at the other power settings, sample was only drawn from the #3 inlet tips on the 1-m rakes. Even at the low power settings, it became apparent that there were problems with some of the inlet tips on the right rake as particle concentrations were highly variable and several seemed to be entirely blocked. The problems became more severe as the test proceeded as variable concentrations began to be observed on several of the #2 engine rake tips. Size distributions recorded on the “bad” tips showed prominent nucleation modes, something the dry nitrogen dilution gas was meant to suppress. Rick suggested that the lines may have been filled with condensed water, which promotes nucleation; LaRC H2O vapor measurements seemed to support this idea as abnormally high concentrations were seen in many of the 1-m sampling lines. The problem became more severe as the test proceeded and at about the 2 hour point, when a sampling line came loose on the #3 engine, 30-m inlet probe at 65% thrust, engine power was dropped to 4% and an exhaust plume chemistry experiment ensued. At the 2.5 hour mark, the dry dilution gas supply ran dry. The tests were halted about 7:15 pm.

- A post-run debriefing was held in the AEDC trailer to discuss the sampling line problem, the apparent high usage of dry N2, and a resolution to the AFRL inlet issue. It was decided that only the #3 and 4 inlet tips on the two, 1-m rakes would be used in subsequent tests. Sample

lines emanating from the other tips would be blocked. This would reduce the “dump” flow (procedure of continuously drawing high volumes of sample and dilution flow through unselected inlet tips) requirement by 60%, which would conserve a great deal of N2. To further reduce N2 consumption. The “dump” flow tactic would be abandoned in favor of purging—blowing flow out the inlet tips--the unselected probes with about 5 lpm dry N2. The team decided to connect the AFRL gas sampling lines to two of the abandoned particle inlet tips that were positioned in the engine’s core flow. Brass ferules and additional tie-downs will also be installed on the 30-m sampling to prevent them from pulling apart and detaching from the surface, as they had during the mapping test. The team decided to begin work at 6:30 am Tuesday to affect the changes and prepare for a possible 9 am exhaust characterization test. The later start will also allow time for delivery of additional dry N2 “six-packs” to the site and to calibrate and adjust positions of the instrument suite.

- While the near-field investigators encountered a number of challenges during the engine runs, the downstream team enjoyed ideal conditions for plume sampling as the prevailing winds transported exhaust emissions straight down the ramp to their sampling inlets. Realizing that Monday was the only day this week that would provide favorable winds, ARI detached from the 1-m sampling group and parked their van on the perimeter of the ramp, about 200 m downstream of the engines. Running their instrument suite along with an EEPS provided by UTRC, they were able to record excellent measurements of plume gas-phase and particle composition, throughout the afternoon/evening. Here are some of Scott’s comments.

********** Downstream Samplin’ Team Report **********

The 200 meter (which is probably more like 150m) trailer saw some nice hits. I don't think engine thrust is a problem at these distances. The wind speed goes up 3-5 m/s from idle to full power during the shakedown at the 200 m probe site. When the truck was switched to the left side of the ramp, it was technically closer to the aircraft centerline. At 65% power, wind speed went up 5 m/s. If the wind comes back to favor working downwind, I think what we did was pretty safe.

Prelim results:

Figure 5-top panel shows methane production at idle 14:07-14:09 local time, the bottom panel shows methane destruction at higher power 14:40 - 14:43. Each have HONO!! Astonishingly, the values are a bit higher than we were expecting relative to NOx. We'll see how that bears out on further analysis.

Additionally:

a) All instruments on the truck were seeing exhaust when we expected them to

b) Rick would call out the engine conditions, but NOx/CO2 pretty much told us exactly where the throttle was. This dataset will be our first definitive measurement of ethene, HCHO and CO at the higher powers.
c) EEPS performed very well; Berk started using the front panel display as his plume detector as it relates to EEPS... actually at 65% mapping we had pretty steady state CO2, that is it was elevated above background by ~100 ppmv with a modulation of +/-50 ppmv on a 4-8 second plume basis. *I think that the SMPS and the EEPS can be compared with a little averaging during that power condition*.
d) AMS saw Organic PM in the wind advected plumes (a true first) at idle.
e) AMS saw plenty of Sulfate but I haven't seen this myself yet.
f) This is neat. At idle, we see that the direct emissions of NO2 are leading to minor O3 enhancements in the first minute of plume evolution. This tapered dramatically as the sun went down. It turned out the timing of the test for this aspect was perfect.
g) We have a lot of data to follow up, but the HCHO to ethene ratio and the butadiene to benzene ratio *may* have been different, but we didn't see anything dramatic there. But the effect we were predicting was going to be somewhat subtle.

Figure 1. Robert and Steve batten down the hatches on the #2 engine sampling rake.

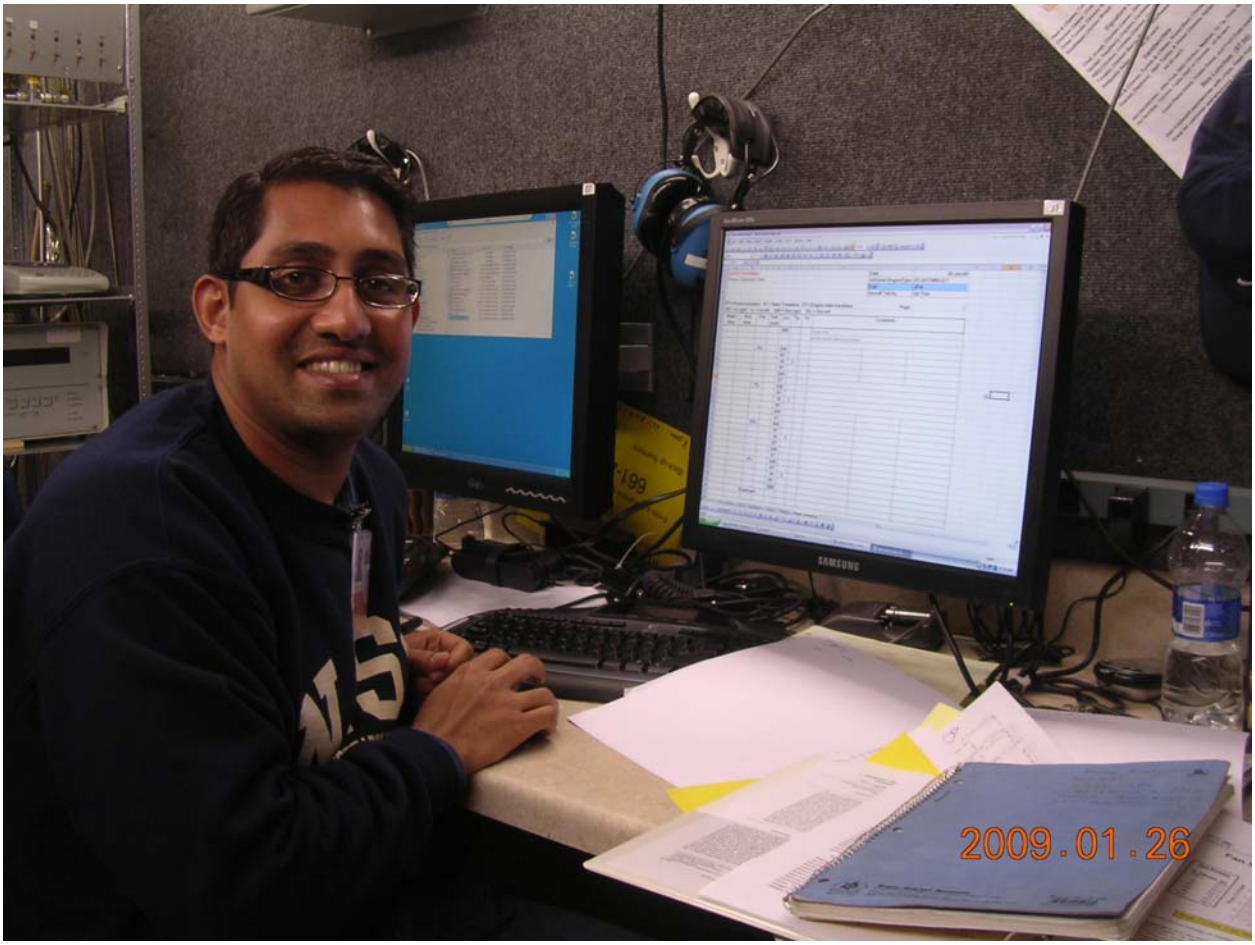

Figure 2. Prem works EXCEL magic to develop run-sheets for the day's shakedown and exhaust mapping tests.

Figure 3. Steve works on the sample distribution system in the MST trailer.

Figure 4. Jim modifies the 30-m sampling lines, replacing the flexible tubing with hard stainless steel and installing more cable ties. Note the ARI equipment van strategically parked downstream, off the aircraft's left wing.

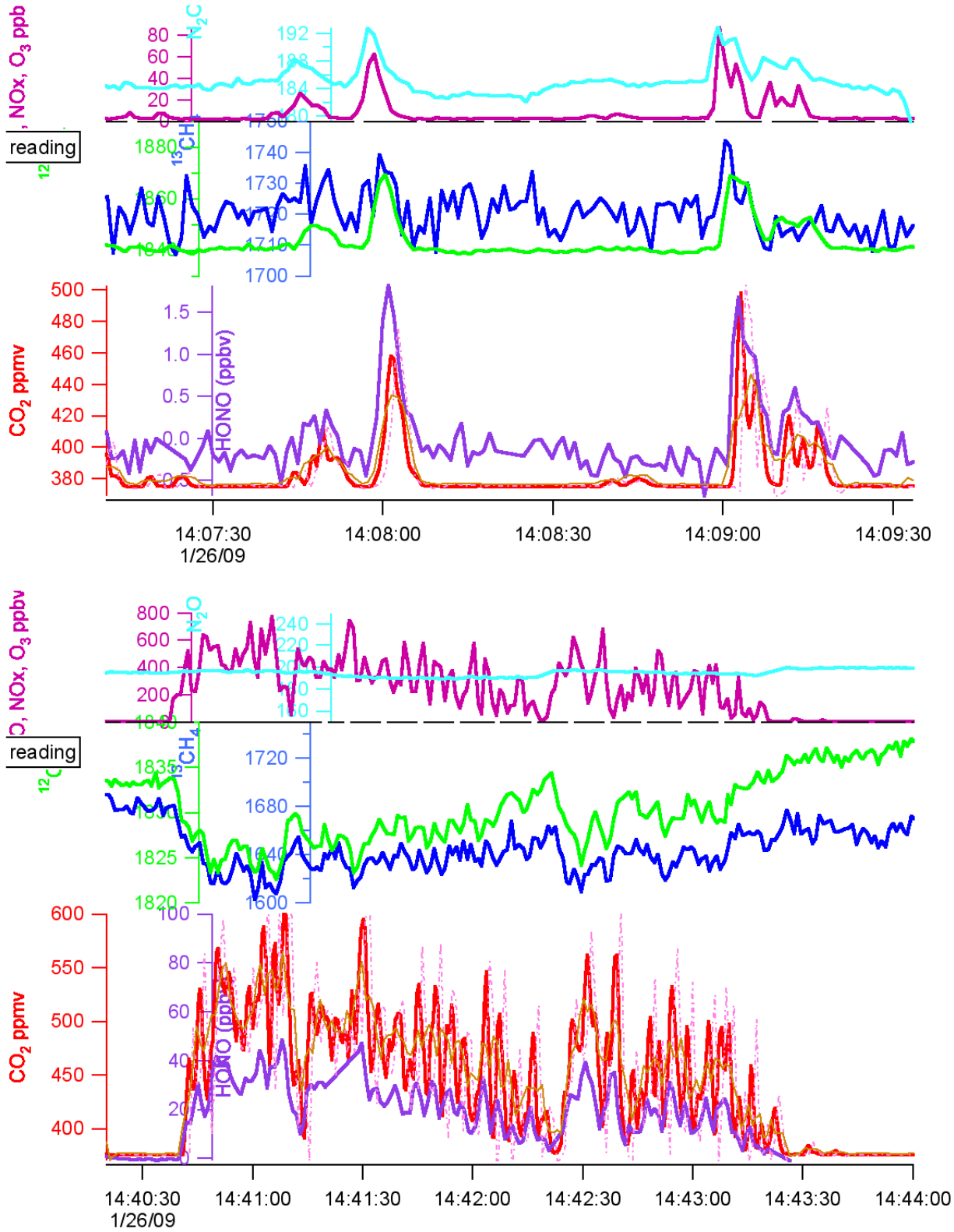

Figure 5. Time series of gas-phase data recorded by the downstream team.