

## AAFEX-II Status Report #8 – 29 March 2011

**Primary Activities:** Three tests with HRJ

**Weather:** Sunny and clear all day; 46 F at 0430 warming to 72 F at 1430. Winds very calm in the morning, then picking up a slight northerly component during midday.

**New Participants:** In addition to Mark Johnson (Rolls Royce) and Anuj Bhargava (Pratt and Whitney) who joined the E-31 crew on Monday, Dave Christie (Honeywell) and Wendy Bailey (Transport Canada)

**Summary:** Most participants were on site shortly after 4 am to prepare for the scheduled 6 am engine start. The day's plan called for conducting cold and warm phase emissions test of the HRJ fuel. To prevent fuel system leaks, a \$150K, 3000 gal aliquot of tallow HRJ was loaded in #3 main tank just prior to the morning's test. A pre-test briefing was held at 5:15 am and participants were snug in their trailers by 5:55 am, awaiting engine start. Engines were spun up for Test Run 4 shortly after 6 am and all went very smoothly as engine power was initially ramped from idle to 30% to burn residual JP-8 from the #3 engine fuel supply system. PM and SO<sub>2</sub> emissions were observed during the run to identify fuel transition. When emissions were stable, power was reduced to 4% and data were recorded from the 1 and 30 inlets as power was increased to 7, 30, 65, 85, and 100% of maximum rated thrust. Engine power was reduced to idle at ~7:35 am, which allowed participants to take a short potty break and grab coffee before power was increased to 100% to begin a down ramp of settings at 85, 65, 30, 7 and 4%, this time only sampling from probes behind the #3 engine burning HRJ. Longer time was spent at the 7 and 4% settings, with engine #2 extinguished, to allow the ARI mobile laboratory time to repeatedly transect the exhaust at varying downwind distances (Figure 1). Tests were complete and engines were shutdown around 8:45 am.

After receiving an accounting of Test Run 3 fuel burn (<6,000 lbs of the available 18,100) and considering the ideal weather conditions, it was decided that two additional HRJ runs could be conducted during the day, one at 10 am and the other at 1 pm. This was to improve statistics, more firmly establish ambient temperature effects on volatile aerosol emissions and reduce the quantity of fuel that would need to be disposed of as hazardous waste.

AAFEX-II Test Run 5 got underway at 10:03 am, with Donnie (Figure 2) cranking the APU to provide bleed air for spinning up engines 2 and 3. The test matrix was a repeat of the morning plan, with an initial warm-up at 4% power followed by sampling at 4, 7, 30, 65, 85, and 100%, a 10 minute break at idle, then downward stairsteps in power from 100% to 85, 65, 30, 7 and 4. During the intermission starting at 11:15, the ARI mobile lab again made multiple plume crossing to examine plume chemistry, then parked on the southside of the apron to sample advected plumes during the second half of testing. All power points were complete by 12:25 pm; crew and participants took a short lunch break to recharge for the afternoon's testing.

The APU was started at 1:28 pm for AAFEX-II Test Run 6, a repeat of the two previous test plans at warmer ambient temperatures. Data was collected at 1 and 30 m behind both engines during the upward power ramp, then at 1 and 30 behind the starboard engine on the down ramp. Sampling went very smoothly, aided in part by experience gained in the 13 previous hours of engine runs. When the test matrix was complete and to prevent fuel leaks, the engine 3 fuel valve was switched to draw JP-8 from the main fuselage tank to burn out residual HRJ in the fuel manifold. This provided an interesting opportunity to contrast the difference in emissions between HRJ and JP-8 (Figure 3).

Over seven hours of data was recorded during the three tests—here are a few notes and observations.

- The fuel system sprang a slight leak during Run 6 (Figure 4) after the fuel system had soaked in HRJ fuel for about 8 hours. Joe measured a leak rate of 2 drops/second, much less than we witnessed with Sasol during AAFEX-I. Flushing the system with JP-8 quickly resolved the problem.
- Consistent with AAFEX-I FT fuel results and as illustrated in Figure 5, the HRJ produced significant reductions in particle number emissions. At idle, number EIs were a factor of 100 lower than seen with JP-8. The emission benefit decreased with increasing power, but EIs were still reduced by 75% at climb-level thrust (85%). A cursory examination of MAAP data suggests that PM mass emissions follow a similar trend. Although volatile number EIs were also suppressed in downstream measurements, values were not as low as expected, perhaps of minor contamination with of JP-8 as suggested by the non-zero SO<sub>2</sub> emissions observed by Changlie.
- Ambient temperature increased by about 15 C over the course of the three engine runs. This apparently caused a reduction in soot emissions as evidenced in by data shown in Figure 5. A similar temperature trend was noted during AAFEX-I, particularly for power settings less than 65%.
- Berk saw significantly different hydrocarbon emission signatures for the JP-8 and HRJ fuels. Large differences in aromatics was expected because the HRJ is devoid of these compounds, but Berk noted changes in oxygenated species as well—more to come in a future report.
- The E-31 setup seems to finally be in place and the group is down to making measurements on the “E-31” and reference lines. Uncertainties still exist in the overall flow system, but a calibration effort is underway and Dave is optimistic that significant work will be accomplished in the remainder of the engine runs.

#### **Agenda for March 30, 2011**

- Brief at 5:15 am for a 6 am engine run
- est Run 9: FT fuel without sulfur doping
- Test Run 10: 50% HRJ/JP-8 blend (winds permitting)
- Possible Test Run 11: 50% HRJ/JP-8 Blend-Continue to evaluate E-31 system

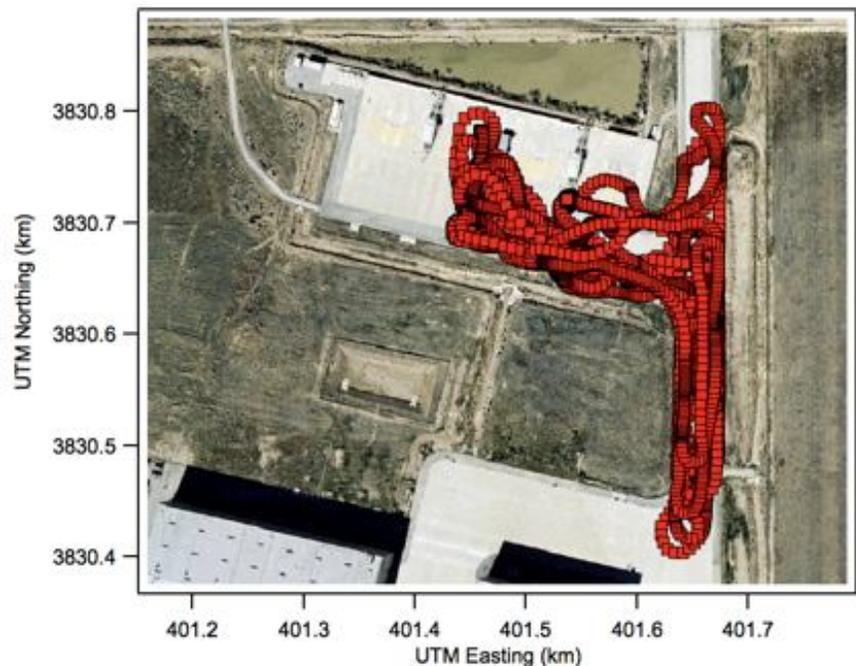


Figure 1. ARI Mobile Lab GPS sampling track during Test Runs 4-6. All tracks driven within the topmost staging area were recorded during aircraft idle operations.



Figure 2. Ground-crew diva MaDonnie sings the blues as he considers the places we could have flown in the 7 hours he was behind the yoke.

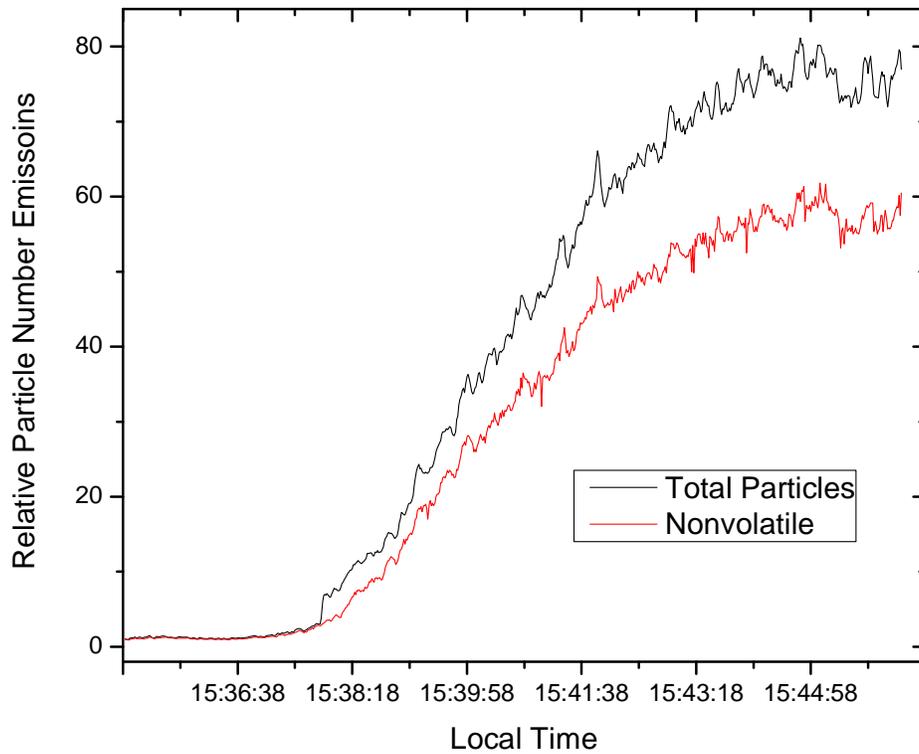


Figure 3. Times series of relative total and nonvolatile particle emissions at 7% engine thrust as the fuel supply to engine 3 was switched from HRJ to JP-8 at around 15:37. (Data courtesy of Eddie Winstead)



Figure 4. Puddle of HRJ fuel under engine 3 after the last test run of the day.

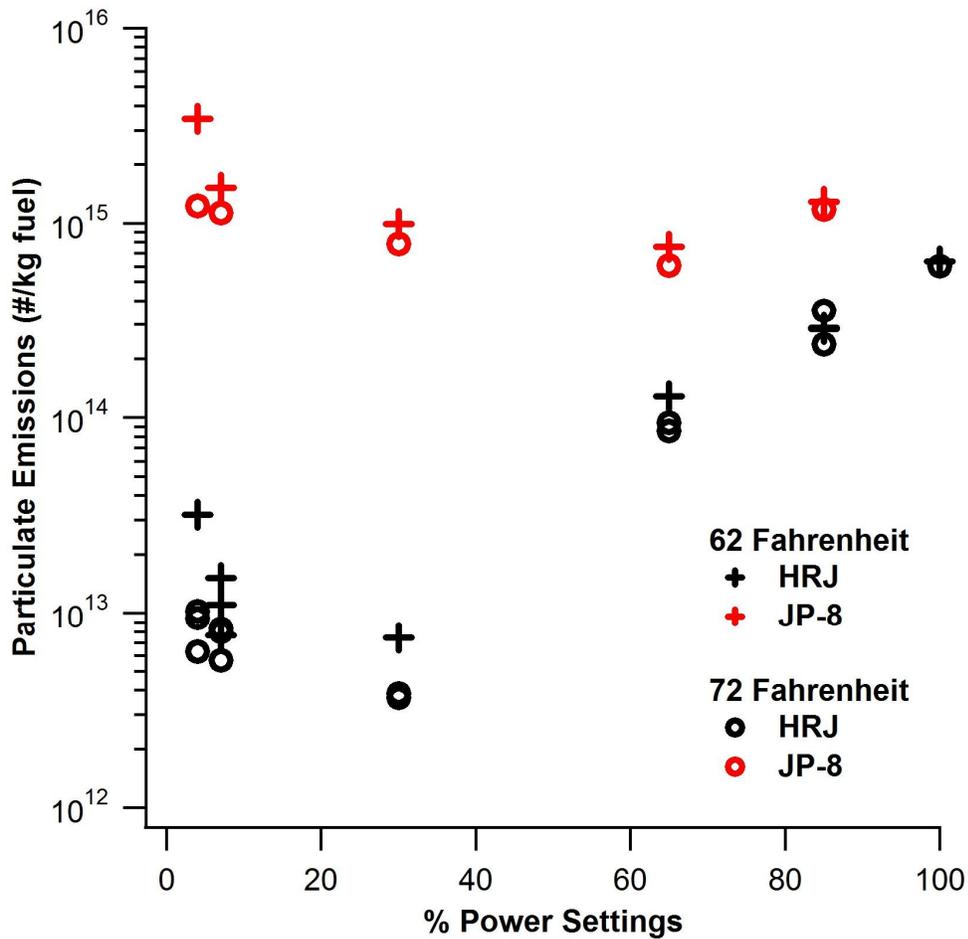


Figure 5. Combined data from the late morning and afternoon test runs showing how both temperature and fuel composition effect particle emissions. Note that relative to JP-8, HRJ combustion resulted in a 99% reduction in nonvolatile particle (soot) emissions at idle and approach (30%) thrust levels, which is comparable to AAFEX-I findings for FT fuels. (Data courtesy of Andreas Beyerdorf). **Preliminary—not for Public Distribution.**