NASA Biofuel Research

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NASA Subsonic Transport System Level Metrics

…. technology for dramatically improving noise, emissions, & performance

TECHNOLOGY BENEFITS*	TECHNOLOGY GENERATIONS (Technology Readiness Level = 4-6)		
	N+1 (2015)	N+2 (2020**)	N+3 (2025)
Noise (cum margin rel. to Stage 4)	-32 dB	-42 dB	-71 dB
LTO NOx Emissions (rel. to CAEP 6)	-60%	-75%	-80%
Cruise NOx Emissions (rel. to 2005 best in class)	-55%	-70%	-80%
Aircraft Fuel/Energy Consumption‡ (rel. to 2005 best in class)	-33%	-50%	-60%

* Projected benefits once technologies are matured and implemented by industry. Benefits vary by vehicle size and mission. N+1 and N+3 values are referenced to a 737-800 with CFM56-7B engines, N+2 values are referenced to a 777-200 with GE90 engines

** ERA's time-phased approach includes advancing "long-pole" technologies to TRL 6 by 2015

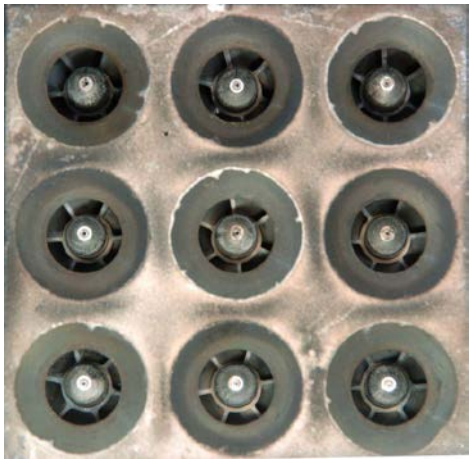
‡ CO_2 emission benefits dependent on life-cycle CO_{2e} per MJ for fuel and/or energy source used

Major Research Areas

- Combustion CFD Model Development
- Validation Experiments
- Low Emissions Fuel Flexible Combustion Concepts
  - N+2 Goals (Environmental Responsible Aircraft Project)
  - N+3 Goals (Fixed Wing Project)
- Alternative Fuels
  - Emissions Characterization

Combustion FlametubeTesting

9-Point Lean Direct Injection Concept

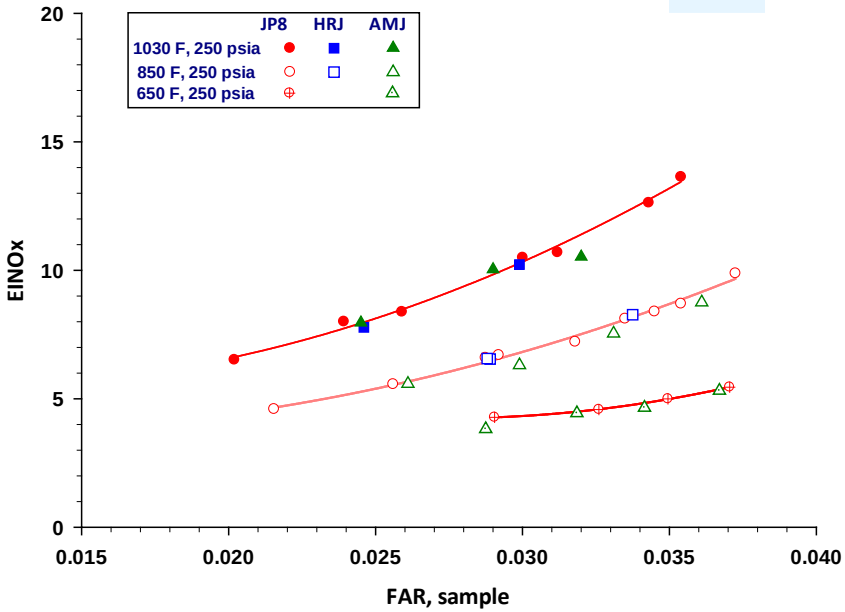


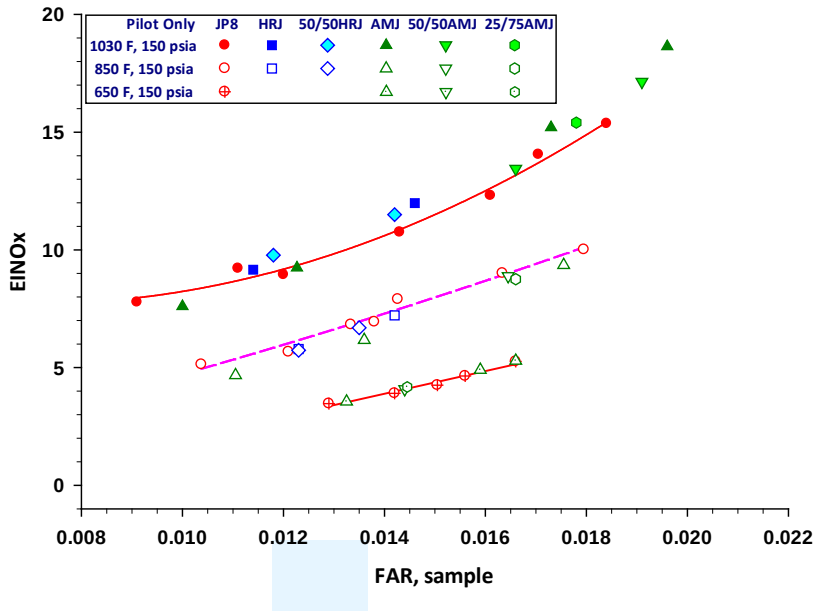
Fuel Properties

TEST	JP-8	HRJ	AMJ
Sulfur (ppm)	400	<1	0.452
Aromatics (%vol)	13.8	~0	6
Distillation, deg C			
IBP	152	153	170
10%	173	181	176
20%	181	193	178
50%	202	222	191
90%	243	259	246
EP	269	270	259
Residue (%vol)	1.2	1.2	1.1
Loss (%vol)	0.5	0.9	1.5
Flash Point, deg C	44	48	52
API Gravity	46.8	53.9	45.9
Freezing Point, deg C	-49	-50	<-79
Viscosity, mm^2/s	4.2	5.8	6.6
Cetane Index	48	69	-
H Content (%mass)	14.1	15.3	14.3
Heat of Combustion (MJ/kg)	43.4	44.1	43.5
Olefins (%vol)	1.6	0.5	1
Specific Gravity	0.793	0.763	0.797

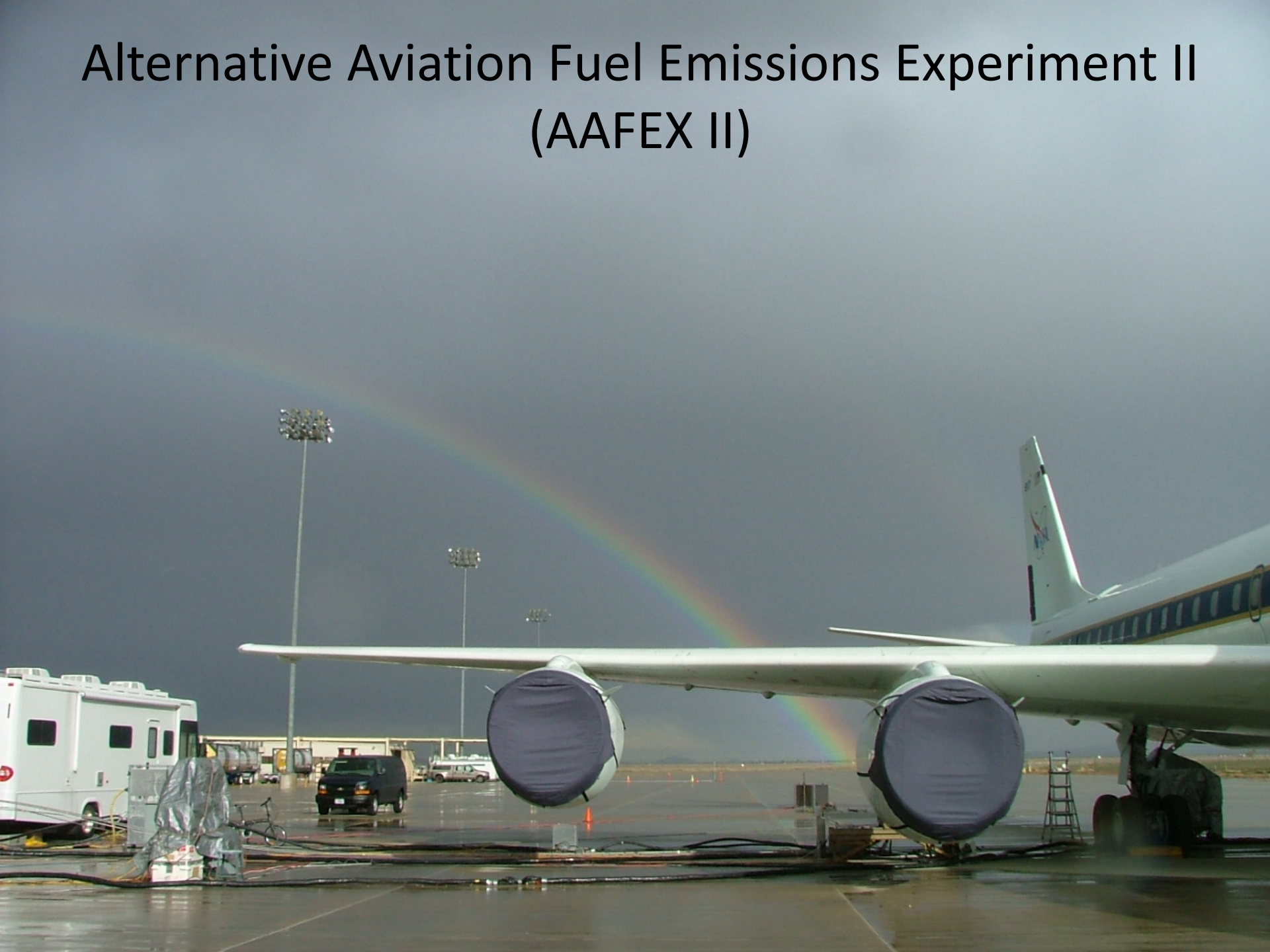
Combustion Flametube Testing Results

NOx Emissions





Alternative Aviation Fuel Emissions Experiment II (AAFEX II)



AAFEX-II: HRJ Fuel Emission Characterization

Location:	**NASA Dryden Aircraft Operations Facility (DAOF)** **Palmdale, California**
Dates:	**March 20 – April 2, 2011**
Aircraft:	**NASA DFRC DC-8, CFM-56-2C engines**
Fuels:	***Standard JP-8** ***Tallow-based HRJ & 50% Blend w/JP-8** ***Coal-based FT & Coal-based FT w/1000ppm S added**
Runtime:	**11 separate Emissions Tests, 30.5 hrs total run time**
Measurements:	**Certification gases, smoke, HAPS, PM number, size, mass, composition, black-carbon content, and morphology**
Sponsors:	**NASA Subsonics Fixed Wing Project, FAA, Air Force**
Participants:	**AEDC, AESO, AFRL, ARI, GRC, LaRC, MIT, MST, MSU, PSU**
E-31 Group:	**UTRC, EPA, Rolls, GE, TSI, NRC-Canada, P&W**

AAFEX-II Project Objectives

1) Evaluate alt fuel effects on engine performance and fuel-handling equipment
2) Determine the effects of alt fuels on engine PM and gas phase emissions
3) Investigate the role of sulfur in regulating volatile aerosol formation in engine exhaust plumes
4) Examine the effects of sample line chemistry and particle losses on emission measurements
5) Conduct tests to support SAE E-31 development of standard exhaust sampling methods

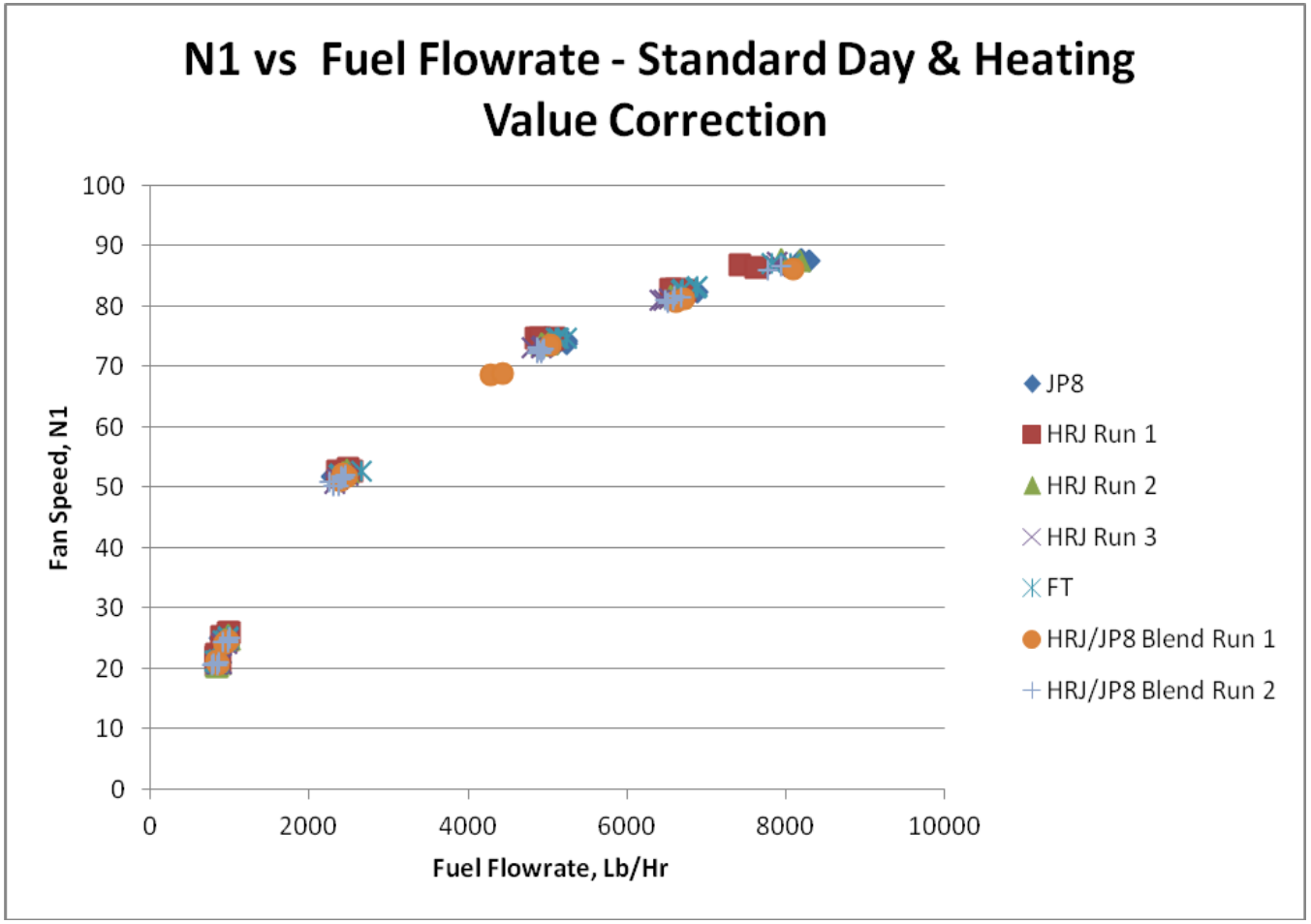
AAFEX-II for Biojet replicated AAFEX-I Test Plan

4, 7, 30, 65, 85, and 100% Thrust Runs; Tests conducted in coldest and hottest parts of day to examine temperature dependencies; had dedicated E-31 probes

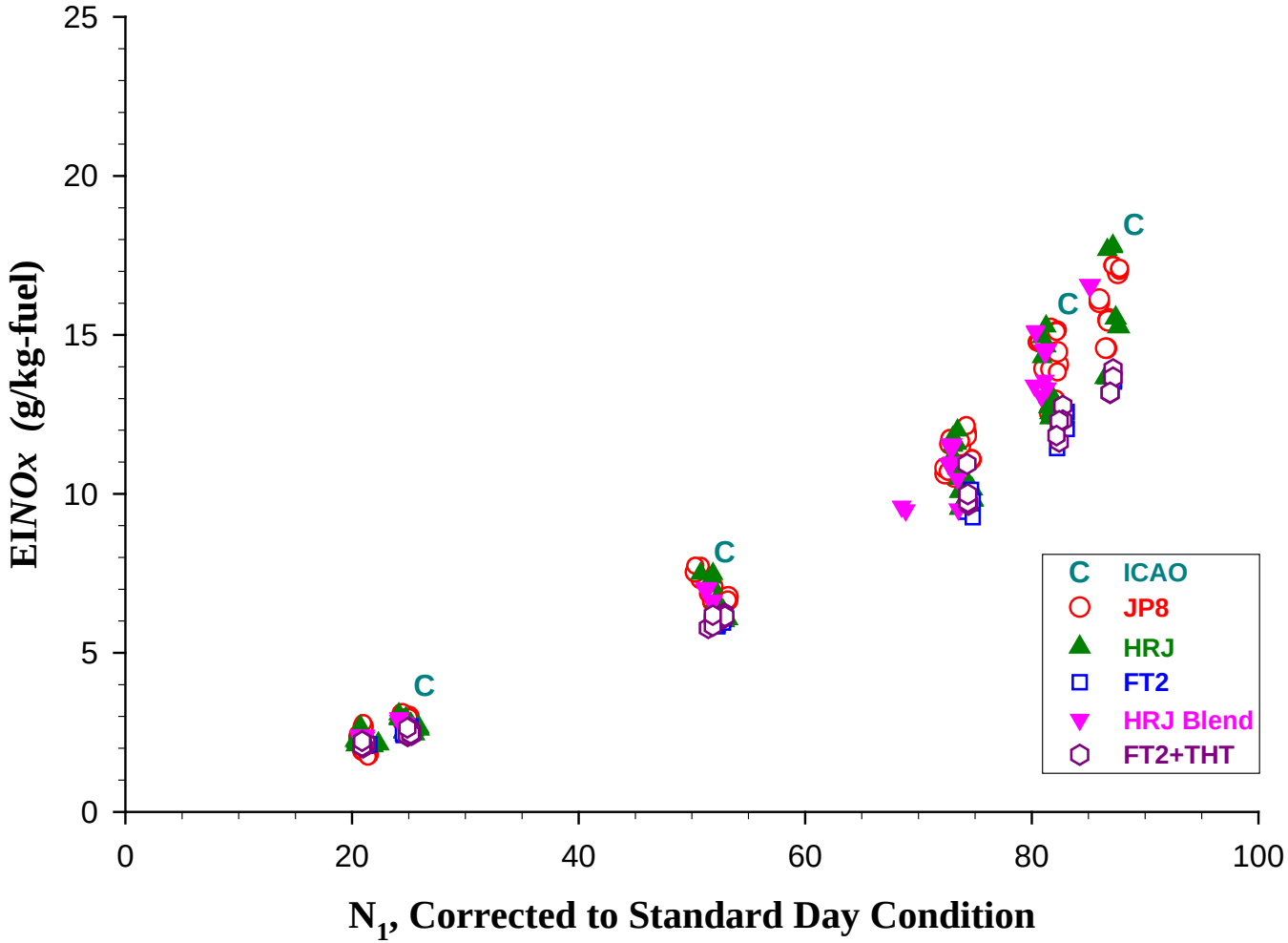
Fuel Properties (Post-Test)

Test	JP-8	Tallow HRJ	FT	HRJ/JP-8	FT+THT
Sulfur (ppm mass)	188	6	4	276	1083
Aromatics (% vol)	21.8	0.4	1.4	10.2	2.1
Initial Boiling Point (°C)	149	158	146	150	151
50% Recovered (°C)	201	209	177	204	177
End Point (°C)	268	254	226	263	224
Flash Point (°C)	46	52	43	46	43
Density @ 15°C (kg/L)	0.811	0.758	0.761	0.783	0.761
Freezing Point (°C) -47	-53	-49	-76	-54	-77
Viscosity @ -20°C (mm^2/s)	4.1	4.9	3.7	4.3	3.2
Hydrogen Content (% mass)	13.5	15.3	15	14.4	15
Smoke Point	22	34	34	31	30
Net Heat of Combustion (MJ/kg)	42.8	43.6	43.8	43.3	43.8
Olefins (% vol)	0.7	0.2	1.6	0.6	1.5

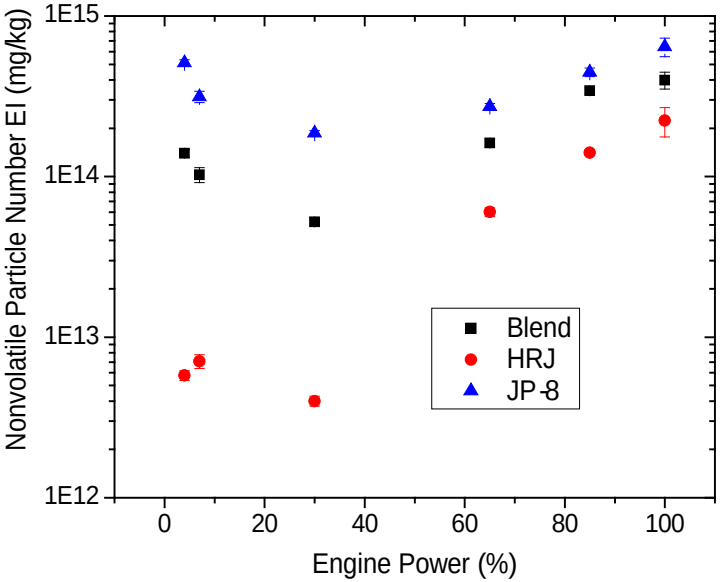
Engine Performance



NOx Emissions



Particulate Emissions



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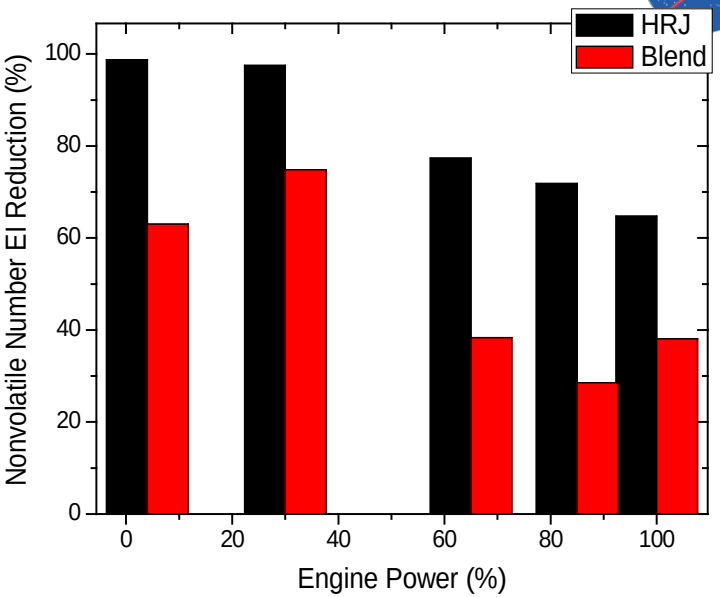
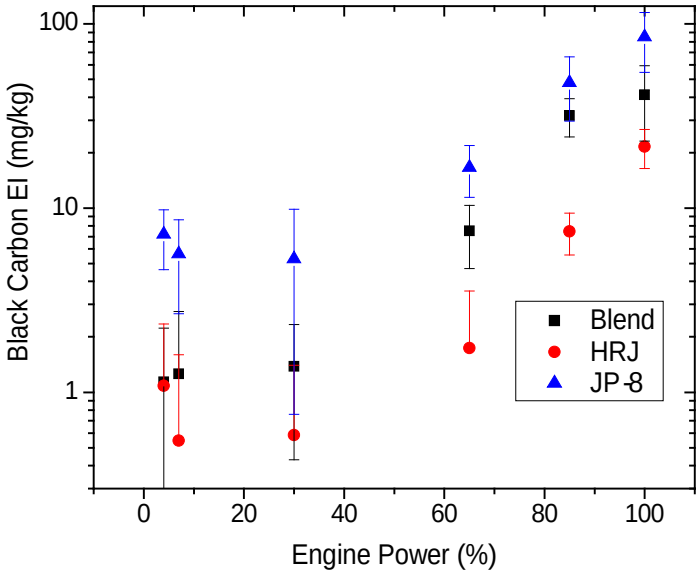
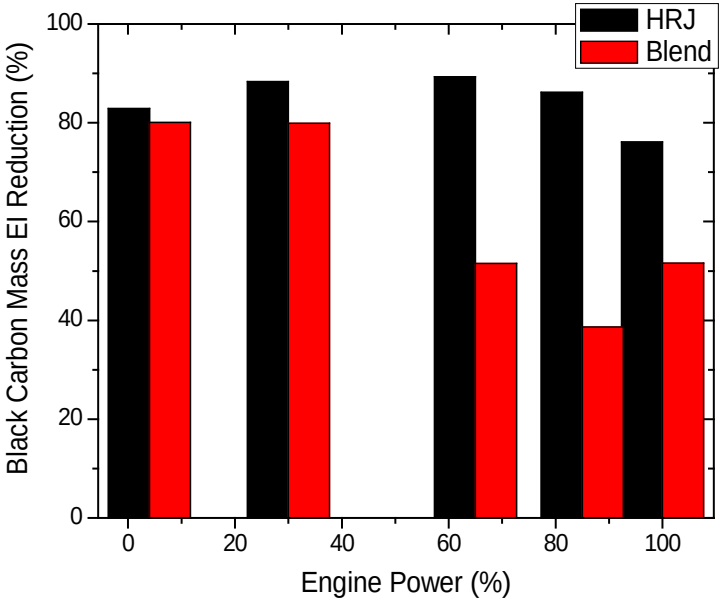
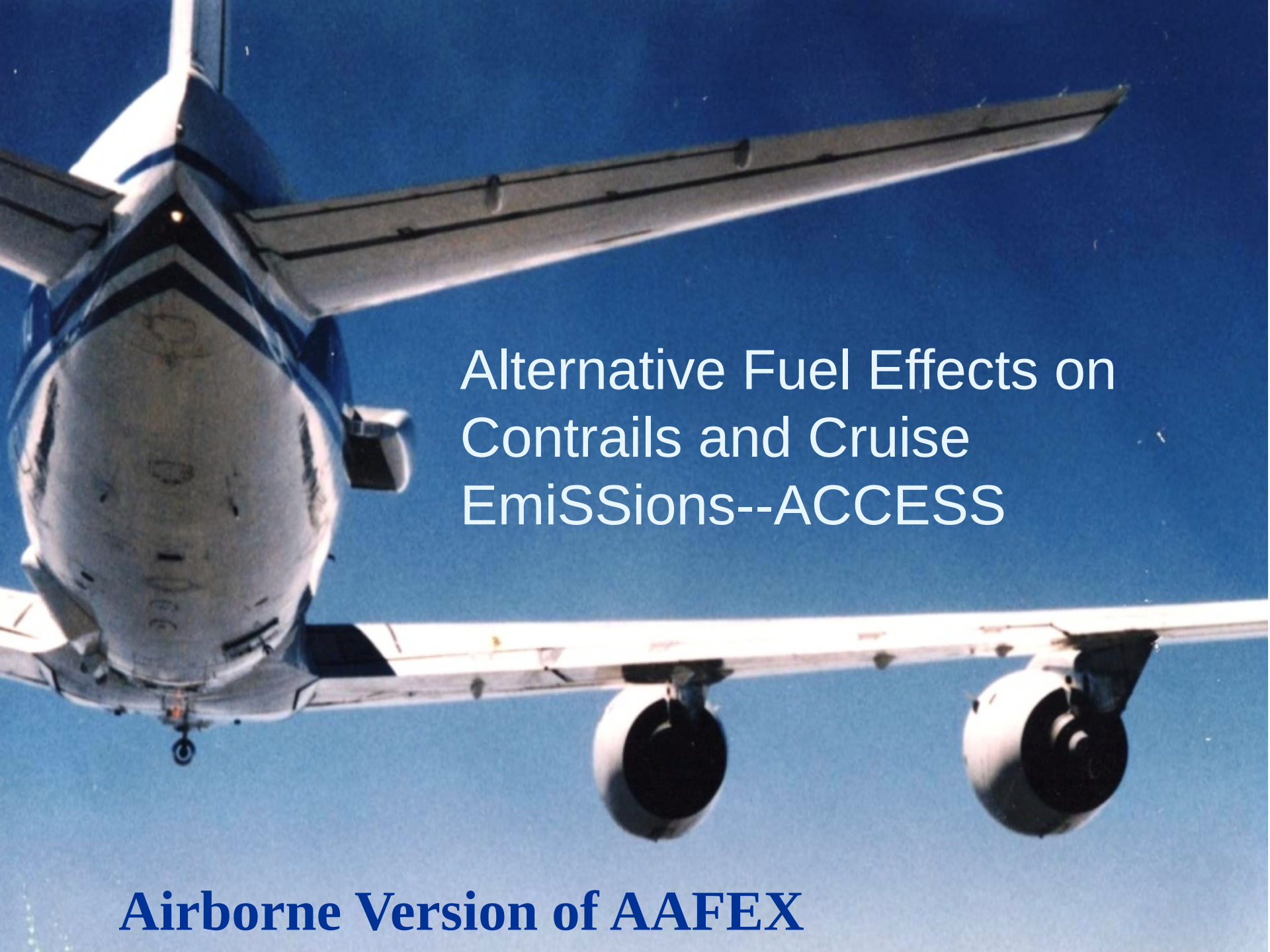




Mass



Some Leakage Evident with Neat Alternative Fuels



Alternative Fuel Effects on Contrails and Cruise EmiSSions--ACCESS

Airborne Version of AAFEX

ACCESS Objectives

1. Characterize fuel effects on aircraft particle and gas phase emissions at cruise altitudes
2. Examine the evolution (growth, changes in composition/microphysical properties) of exhaust and contrail particles as plumes age and become mixed with background air.
3. Investigate the role of black carbon concentrations and properties and fuel sulfur in regulating contrail formation and the microphysical properties of the ice particles.
4. Survey black carbon and gas-phase emissions and contrail properties from commercial aircraft at cruise in air-traffic corridors

Chase Aircraft Measurements

Gas Phase

- CO_2 , H_2O, NOx, CO, Detailed Hydrocarbons (can samples)

Aerosols

- Total and nonvolatile number densities and size distributions
- Black carbon mass and size distribution

Clouds

- Particle size distributions and images
- Ice water content
- Extinction coefficient

Aircraft/State Parameters

- Total and static P and T
- Forward video
- 3D winds

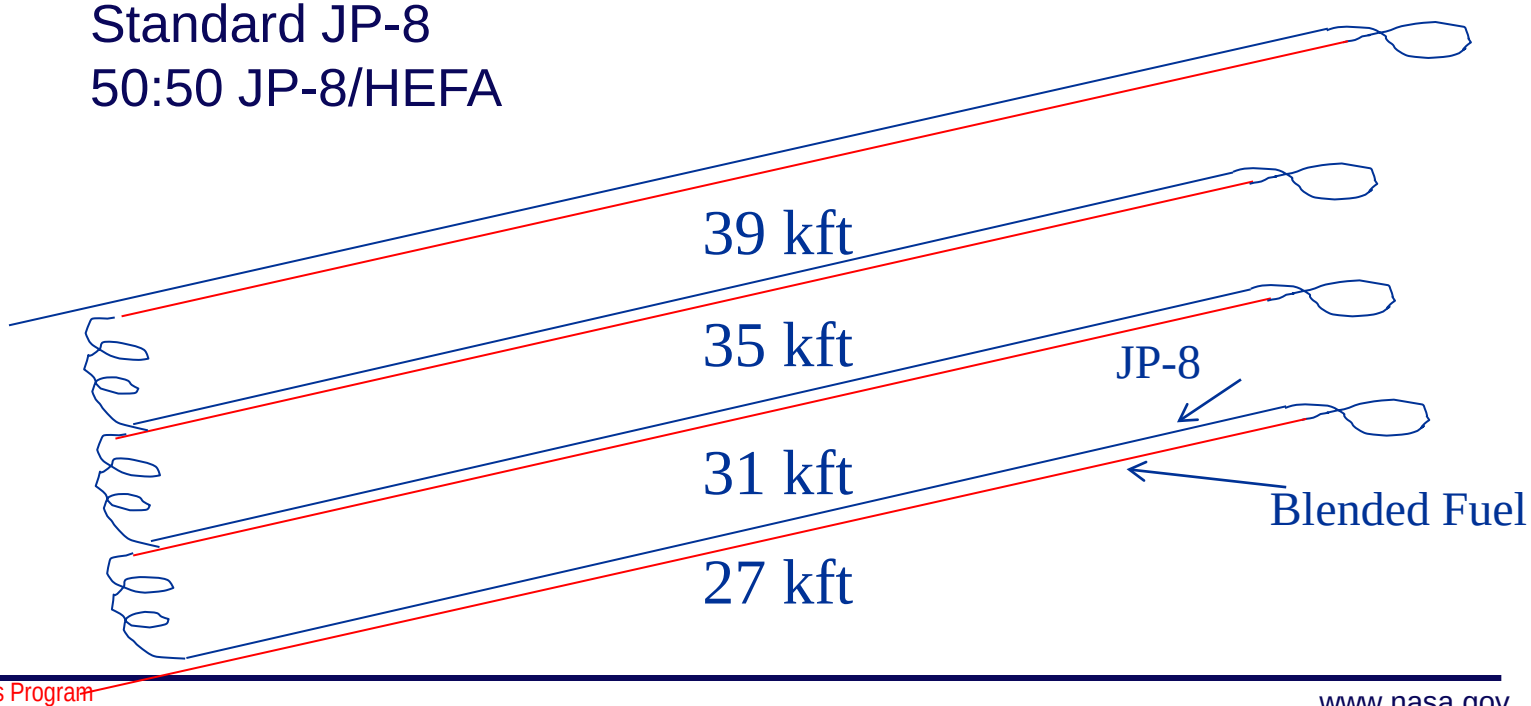
ACESS Test Plan

Location: NASA Dryden Aircraft Operation Facility

Dates: January 15 – March 15, 2013

Aircraft: NASA DC-8: Source Aircraft
NASA Falcon 20: Chase Aircraft

Fuels: Standard JP-8
50:50 JP-8/HEFA



Questions?