National Aeronautics and Space Administration

Alternative Aviation Fuel Experiment II (AAFEX II) Overview

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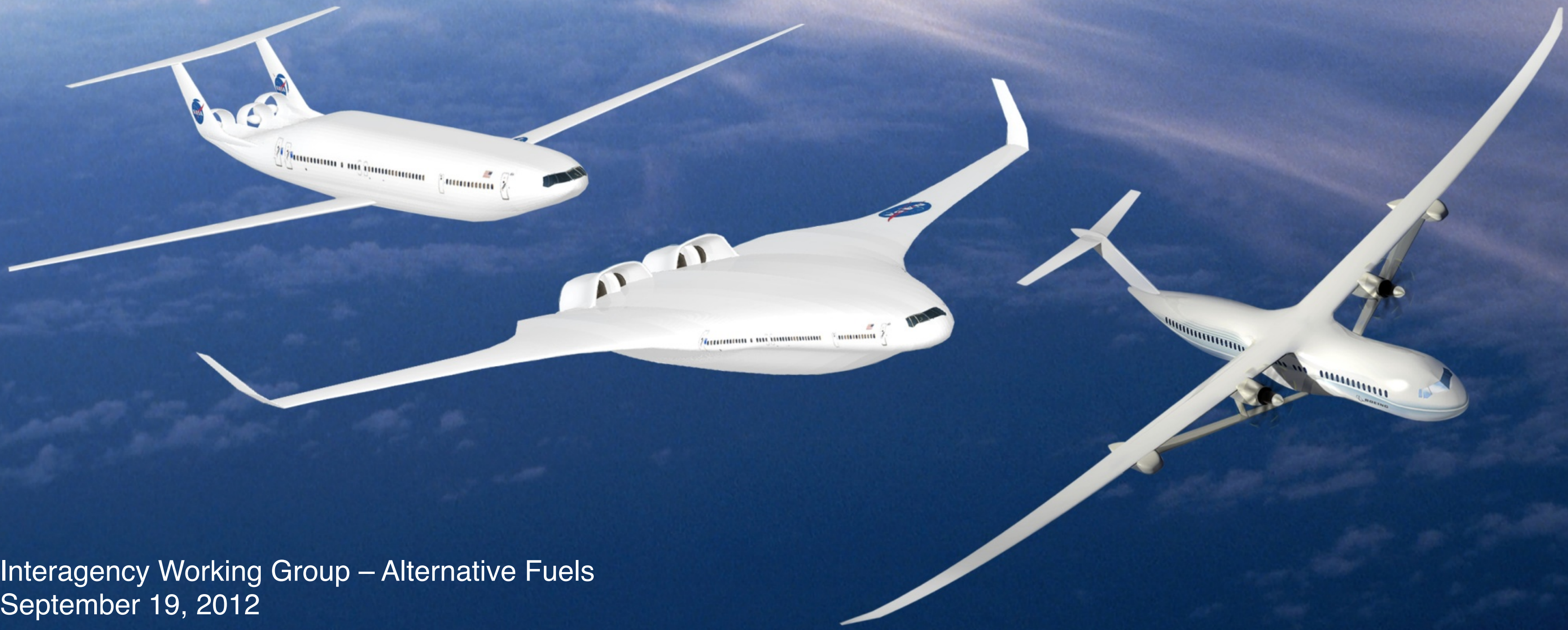
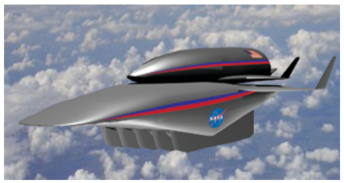


Interagency Working Group – Alternative Fuels
September 19, 2012

NASA Aeronautics Programs



Fundamental Aeronautics Program

Integrated Systems Research Program

Airspace Systems Program




Aviation Safety Program

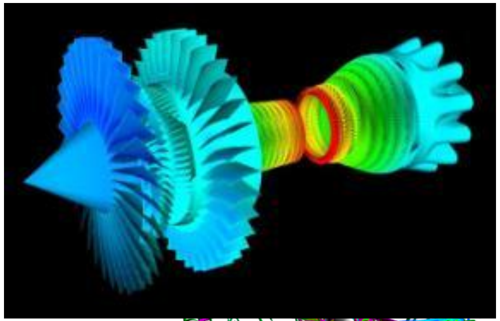


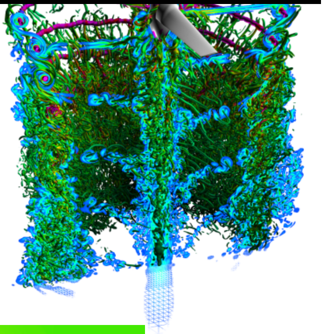
Aeronautics Test Program


Fundamental Aeronautics Program

Goal:

To achieve technological capabilities necessary to overcome national challenges in air transportation including reduced noise, emissions, and fuel consumption, increased mobility through a faster means of transportation, and the ability to ascend/descend at very high speeds through atmospheres.



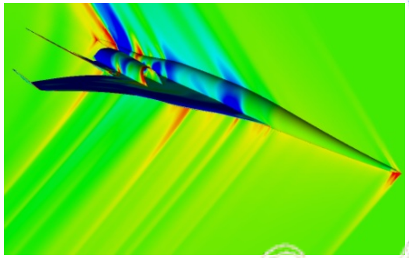


Subsonic Fixed Wing (SFW)

Explore and develop tools, technologies, concepts, and knowledge for improved energy efficiency and environmental compatibility for sustained growth of commercial aviation

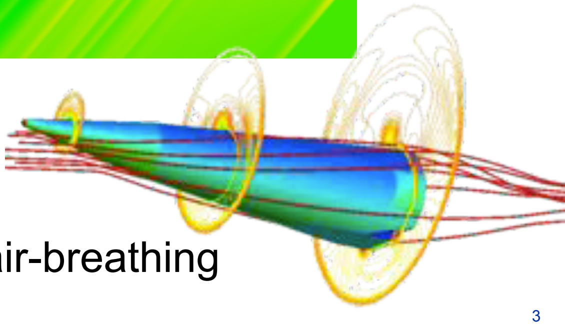
Subsonic Rotary Wing (SRW)

Enable radical changes in the transportation system through advanced concept rotary wing vehicles



Supersonics (SUP)

Develop tools, technologies and knowledge to overcome the environmental & performance barriers to practical civil supersonic airliners.

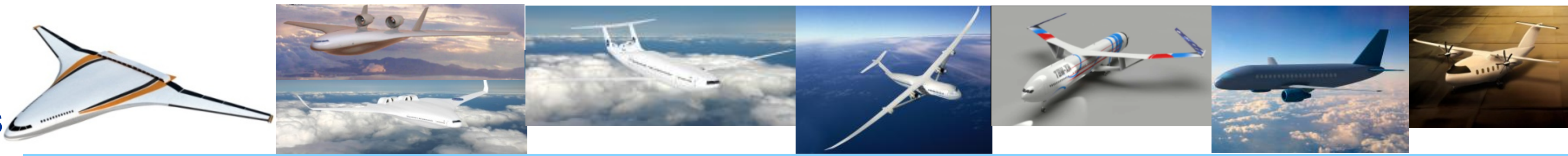


Hypersonics (HYP)

Develop tools, technologies and knowledge to enable hypersonic air-breathing vehicles and high-mass entry into planetary atmospheres.

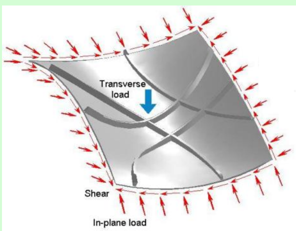
SFW: Diversified Portfolio Addressing N+3 Goals

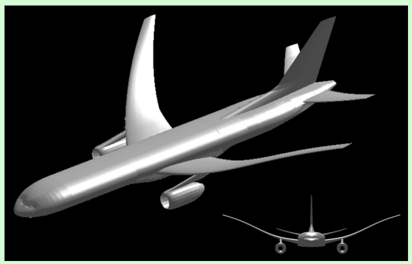
N+3 Vehicle Concepts

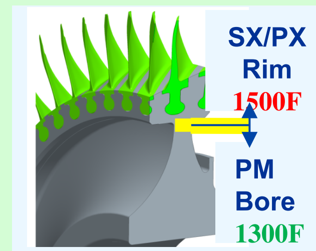


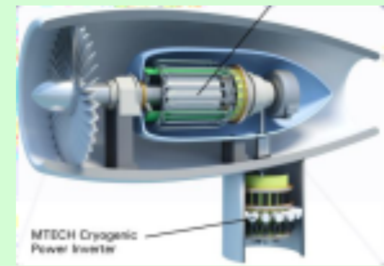
Enduring Challenges

Reduce Drag, Weight, TSEC, Emissions and Noise









Tailored Fuselage

High AR Elastic Wing

Quiet, Simplified High-Lift

High Eff. Small Gas Generator

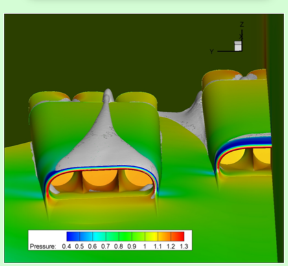
Hybrid Electric Propulsion

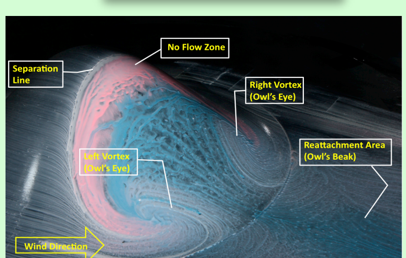
Propulsion Airframe Integration

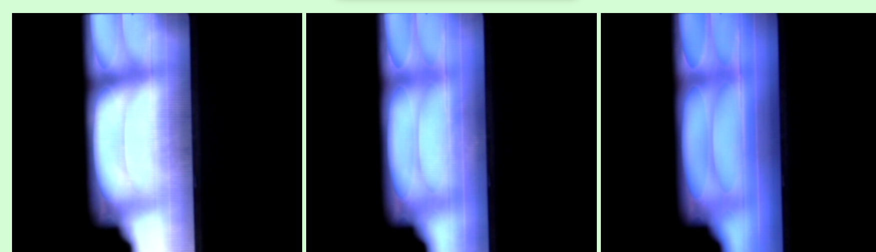
Tools

Alternative Fuels

Technical Challenges







AAFEX-II Experiment and Data Dissemination

PROBLEM

Need to determine effects of synthetic alternative fuels on aircraft emissions

OBJECTIVE

Perform static aircraft engine testing using Hydrotreated Renewable Jet (HRJ) and other fuels to determine effects on engine performance and emissions. Also, examine methodologies for particle sampling to assist the SAE –E-31 Aircraft Particle Measurement Subcommittee in developing a standard particle sampling technique.

APPROACH

Utilize the NASA DC-8 aircraft at the Dryden Operational Facility in Palmdale, CA to perform emissions testing using various alternative fuels and a JP-8 reference fuel, and obtain gaseous, solid, and aerosol samples for analysis at 1, 30, and 150 meters downstream of the aircraft engine exhaust.

AAFEX-II Test

RESULTS

- Over 30 hours of engine testing conducted in April 2011 with participants from NASA LaRC, DFRC, and GRC, FAA, AFRL, AEDC, MST, NAVY AESO, EPA, P&W, GE, RR, UTRC, PSU, as well as several particle measurement instrument companies.
- Gaseous and particulate emissions obtained for neat HRJ, HRJ/JP-8 blend, JP-8, F-T low sulfur, and F-T high sulfur fuels.
- Results showed that HRJ fuel and blends had minor effects on gaseous emissions. No effect on engine performance was evident within the accuracy of the data. Volatile and non-volatile combustion generated particulates substantially reduced when the engine was operated on HRJ Fuel.
- A workshop was held in January, 2012 in Nashville, TN after the AIAA Aerospace Sciences Meeting where all participants presented their findings. An invited session was held at the AIAA JPC Meeting in August, 2012 where four invited presentations compared results from the AAFEX I and II experiments.

SIGNIFICANCE

Results will be used to determine effects of several alternative fuels and fuel sulfur on engine performance and emissions. Particle sampling methodology experiments will directly support SAE E-31 subcommittee development of a standard for particulate sampling.

The Alternative Aviation Fuels Experiment

Objectives

- Evaluate engine performance with alternative fuels
- Determine the effects of alternative fuels and ambient conditions on particulates and gas phase emissions
- Study volatile aerosols that condense in plume and impact of fuel composition

Fuels Evaluated

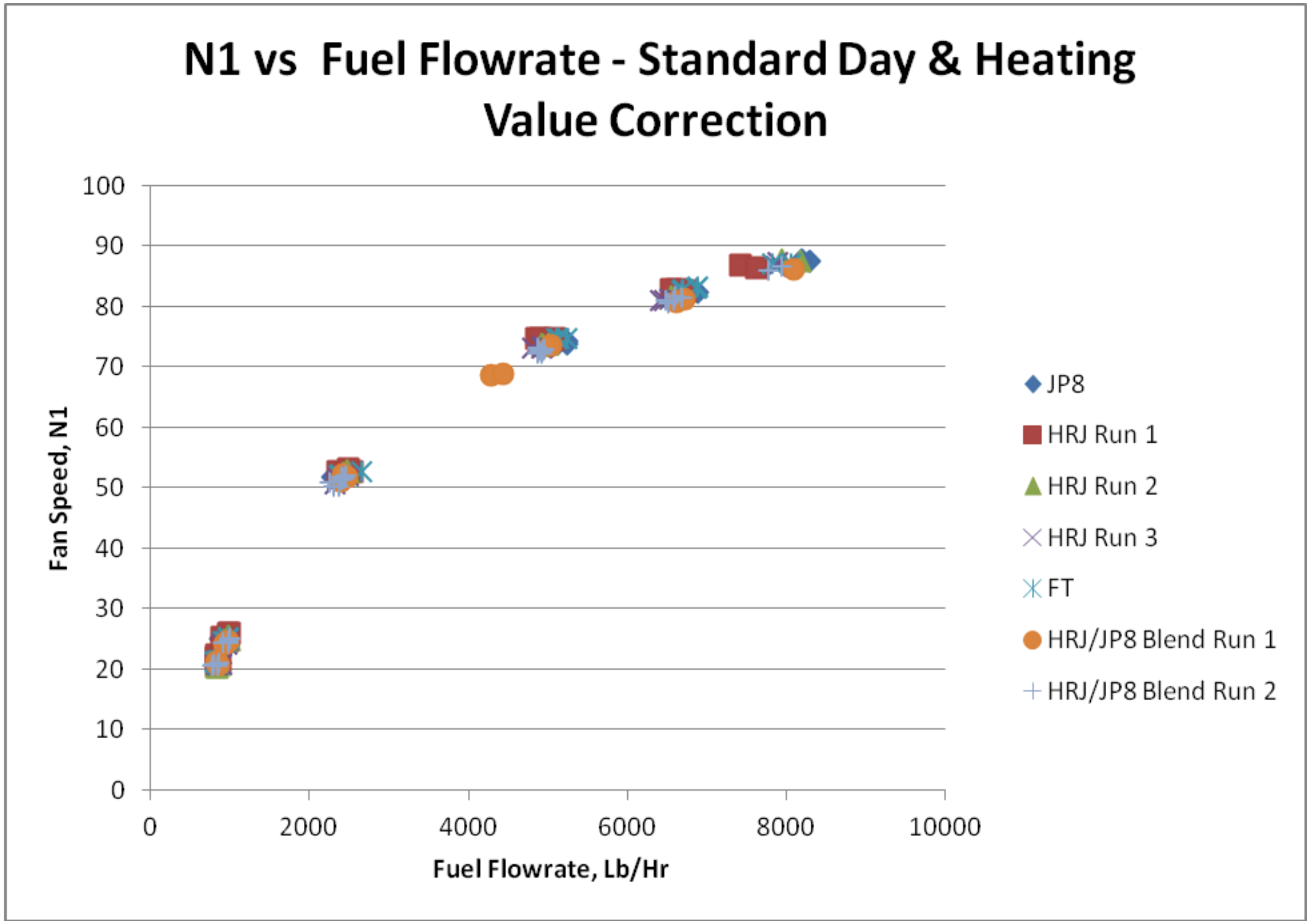
- JP-8
- JP-8/HRJ Blend
- Tallow HRJ
- Sasol FT (coal)
- Sasol FT + ~1000 ppm sulfur

Engine Conditions

- 4%, 7%, 30%, 65%, 85%, 100% of rated thrust

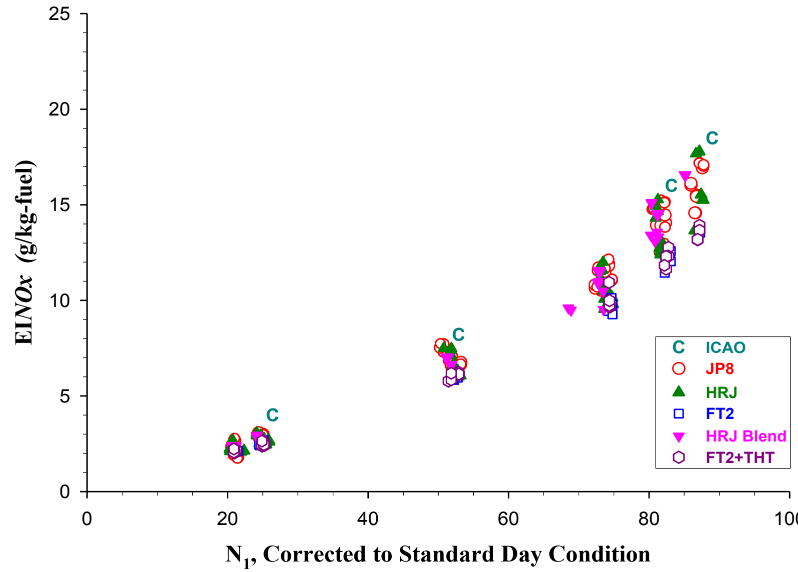

NASA DC-8 Aircraft with CFM56-2C Engines

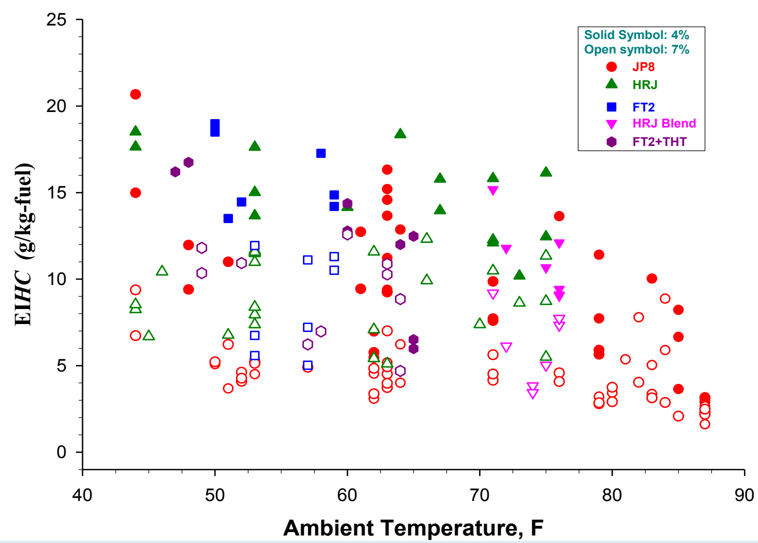
AAFEX II Engine Performance Results



No Measurable Differences in Engine Performance for the Fuels Evaluated

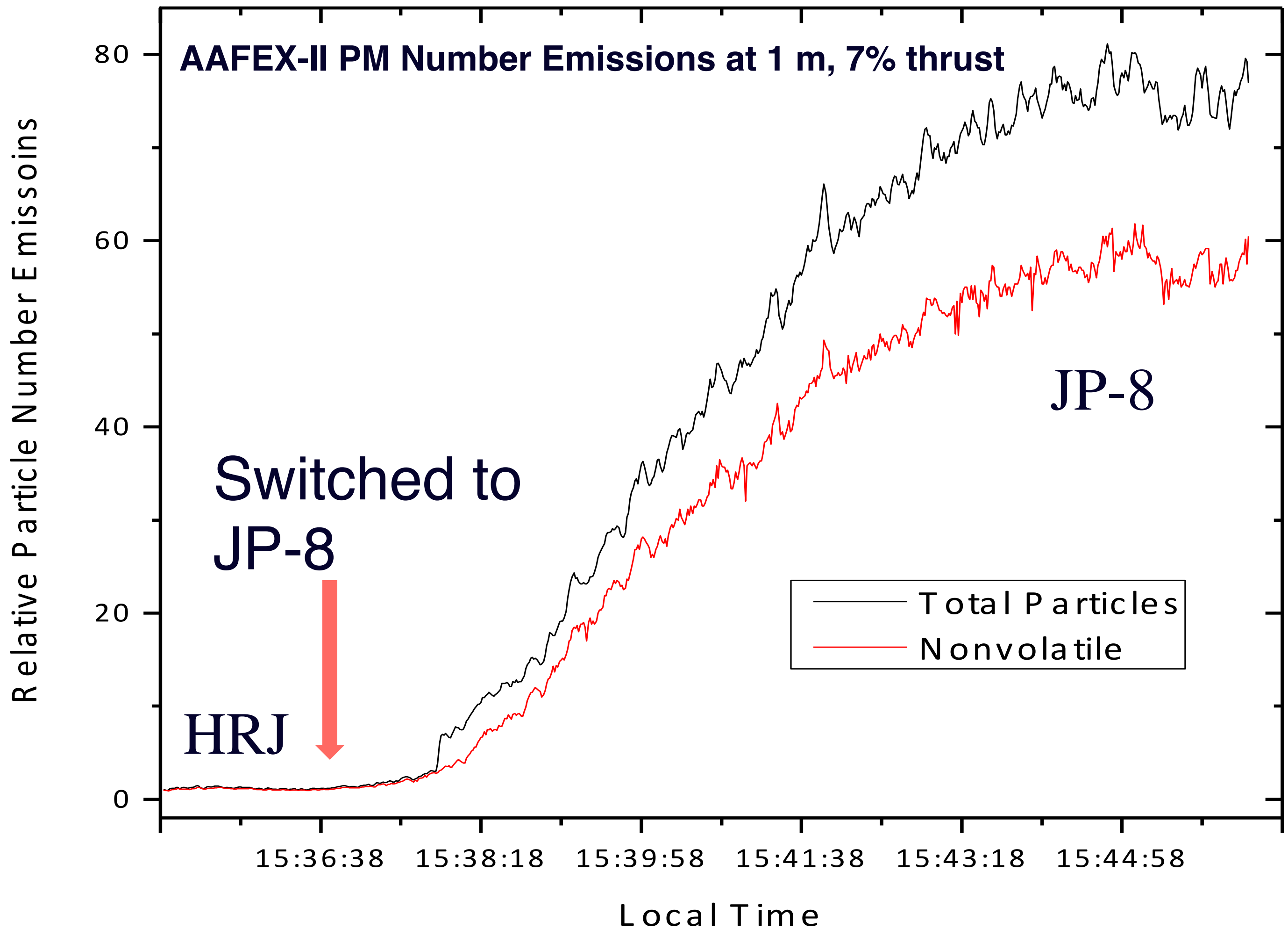
AAFEX II Neat Fuel Results





Neat Fuels Caused Leaks and Had Small Subtle Effects on Gaseous Emissions

AAFEX II Particulate Emissions Results



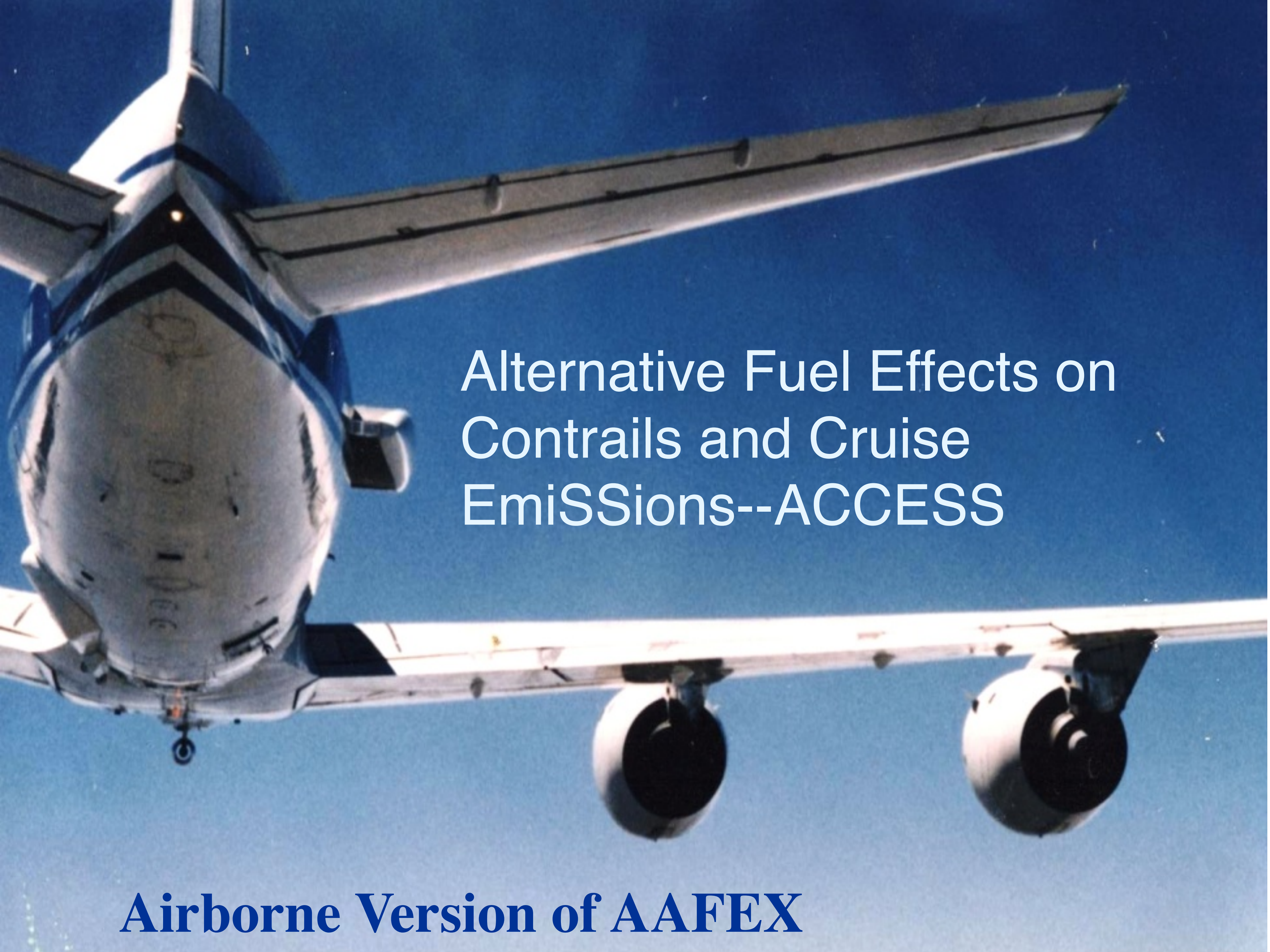
Alternative Fuels Substantially Reduce Particulate Emissions

AAFEX II Key Findings

- Negligible effect of fuel type on engine performance when compared on mass measurement basis and corrected for heating value within accuracy of measurements
- Slight reduction in NOX emissions at higher power conditions for F-T fuel
- Scatter in CO and HC emissions at idle and sub-idle due more to temperature effects than fuel type
- SO2 emissions correlated directly with Sulfur in the fuel as expected
- Fuel leaks encountered with neat HRJ and F-T fuels
- Large reductions in combustion-generated particulates with HRJ fuels. Larger reduction at lower power settings but some reductions also noted at higher power
- Reduced fuel sulfur in the alternative fuels also reduced aerosol formation in the aircraft exhaust plume

Concluding Remarks

- AAFEX II successfully completed during April 2011 at the DFRC Palmad
- Experimental findings and data disseminated at two workshops (copies of presentation attached as reference):
  - January, 2012 in Nashville, TN after the AIAA Aerospace Sciences Meeting where all participants presented their findings.
  - 48th AIAA/ASME/SAE/ASEE Joint Propulsion Conference (30 July to 1 August, 2012), session 168-GEPC/GTE-19. Presentations by: Anderson, et. al, Bulzan, et. al, Corporan, et. Al., and Miake-Lye, et. al.)
- Copies of additional presentations at recent CAAFI, FAA ACCRI, and CRC Aviation Meetings also available as records
- Written publications including NASA TMs, conference papers, and journal articles currently being finalized with publication dates within the next 12 months.



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 In Situ Measurements

<u>Gas Phase</u>
- CO_2 , H_2O, NOx, CO, Detailed Hydrocarbons (can samples)

<u>Aerosols</u>
- Total and nonvolatile number densities and size distributions
- Black carbon mass and size distribution

<u>Clouds</u>
- Particle size distributions and images
- Ice water content
- Extinction coefficient

<u>Aircraft/State Parameters</u>
- Total and static P and T
- Forward video
- 3D winds