NASA Science in Support of Green Aviation

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Potential Environmental Impacts of Aviation

- Reduced air and water quality around airports due to emissions from GSEs, gas-turbine engines, APUs, brakes/tires, etc.
- Altered UT/LS Ozone concentrations due to NOx and particle emissions at cruise
- Long-term climate change due to enhanced atmospheric levels of greenhouse gases from CO2 and H2O emissions
- Short-term, regional changes in atmospheric radiation budgets due to particle emissions and contrail formation

Detailed studies needed to characterize emission sources and to assess the relative changes they induce in the background atmosphere

NASA Science/Aeronautics Collaborations to Assess Aviation's Environmental Impacts

Atmospheric Effects of Aviation Project (AEAP): 1990's

Assessed climate and chemical impacts of aircraft emissions

Broadly engaged science community; sponsored flight missions

Ultra-Efficient Engine Technology (UEET): 2000-2006

Characterized engine/combustor emissions

Research focused on understanding particles

Fundamental Aeronautics Program (FAP): 2007-

Develop and validate tools for predicting emissions

Evaluate alternative fuels and new combustor technology

NASA has led airborne and ground-based studies to:

- Develop efficient ground and airborne sampling systems and sensors
- Survey near-field emissions from commercial aircraft at cruise
- Confirm the role of fuel sulfur in forming volatile exhaust particles
- Examine contrails and aviation impacts on UT/LS chemistry
- Prove that ground tests yield data representative of in-flight emissions
- Obtain first complete particle emission profiles of on-wing engines

We are currently supporting FAP efforts to:

- Improve & standardize exhaust measurement techniques
- Identify & quantify factors controlling soot emissions
- Gain understanding of volatile aerosol formation & growth in aging exhaust plumes
- Gather particle data for model development and validation
- Evaluate emissions from alternative aviation fuels

LaRC and GRC conceived and implemented an experiment to address all of these objectives

Alternative Aviation Fuel Experiment (AAFEX)

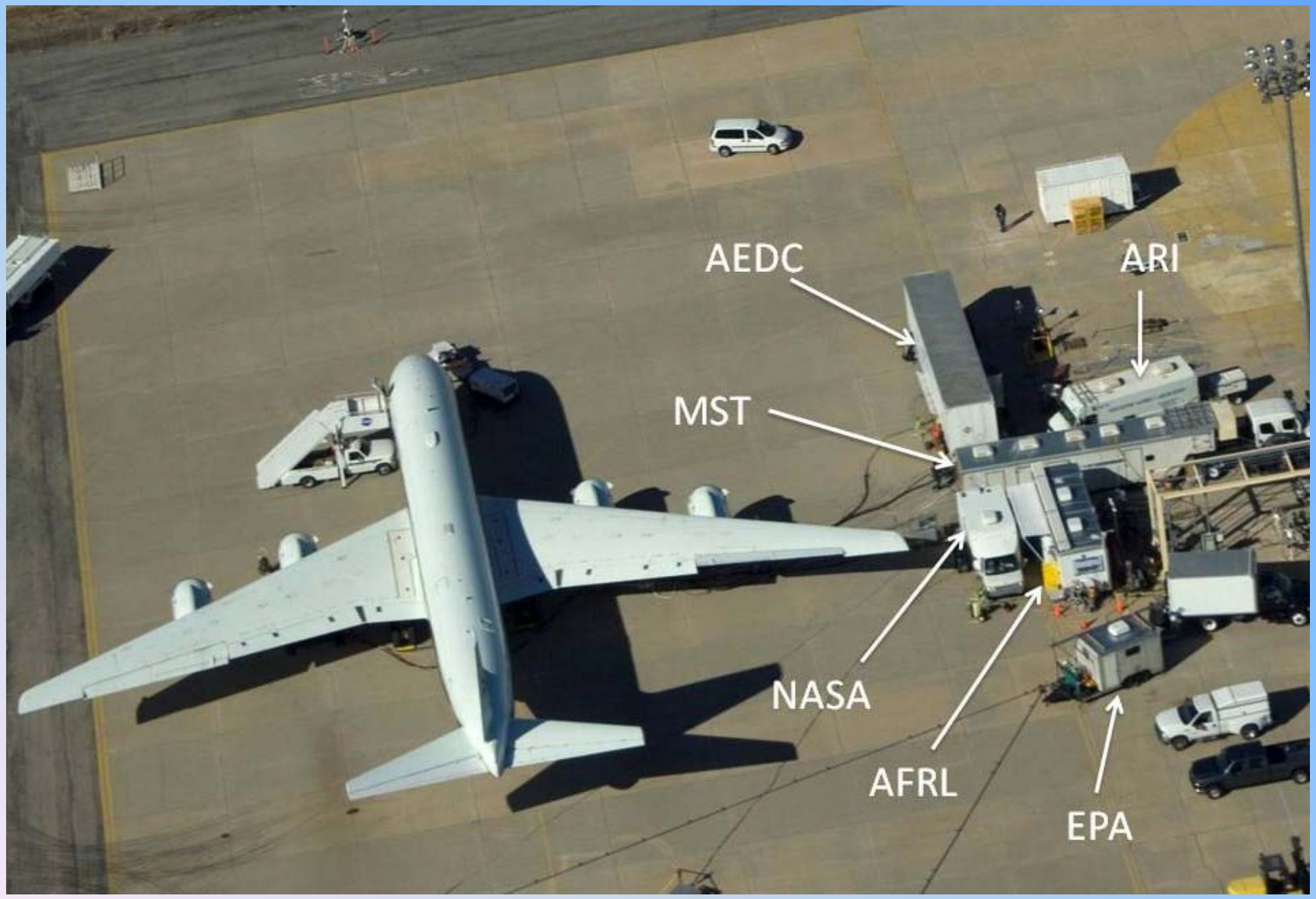
Objectives:

- Evaluate impact of fuels on engine performance and emissions
- Investigate plume chemistry processes
- Inter-compare measurements from different groups
- Create publically accessible data set

Summary of AAFEX Test Plan

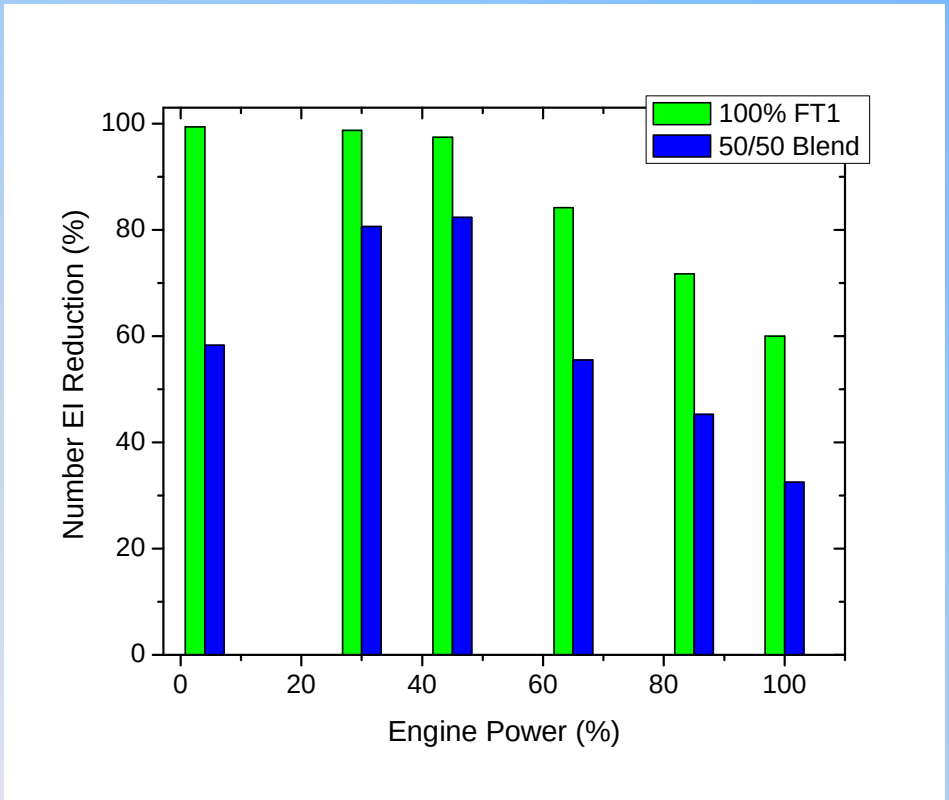
Location:	**NASA Dryden Aircraft Operation Facility**
Dates:	**January 20 – February 3, 2009**
Sponsors:	**NASA, Air Force, EPA, FAA**
Scientist:	**Bruce Anderson, NASA LaRC**
Manager:	**Dan Bulzan, NASA GRC**
Aircraft:	**DC-8 with CFM-56 engines**
Fuel:	**1--Standard JP-8** **2--Shell Fischer-Tropsch Fuel from Natural Gas (FT1)** **3--50/50 JP-8/FT1 blend** **4--Sasol Fischer-Tropsch fuel from Coal (FT2)** **5--50/50 JP-8/FT2 blend**
Runtime:	**~35 hours total**

AAFEX Test Site

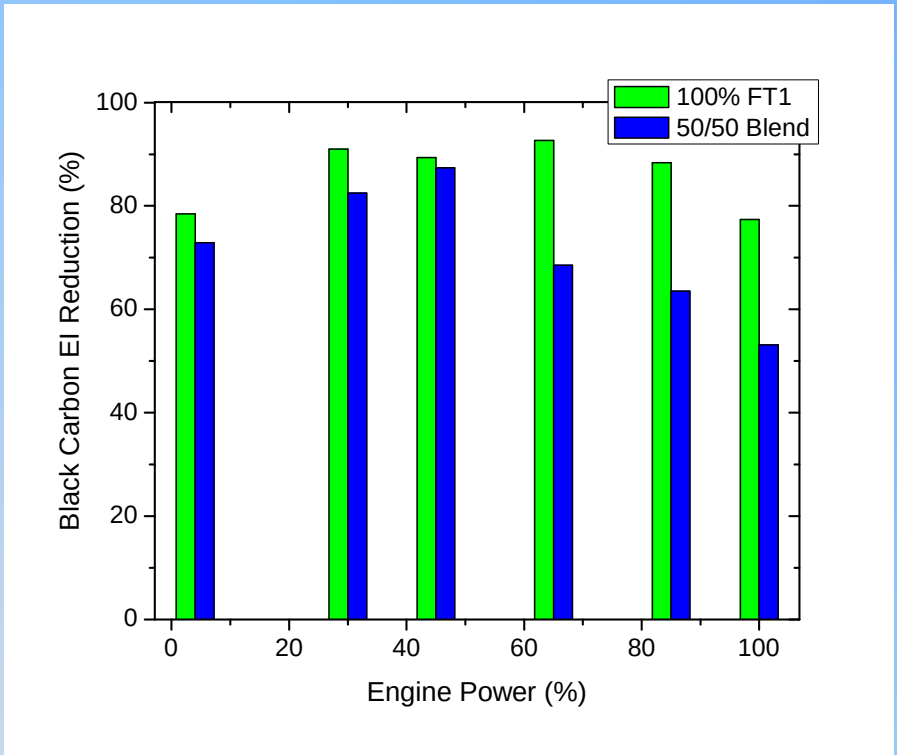


Boeing, GE, Pratt and Whitney, CMU, Harvard, MSU, UCSD, and UTRC also participated

Synthetic Fuels Greatly Reduce Particle Emissions

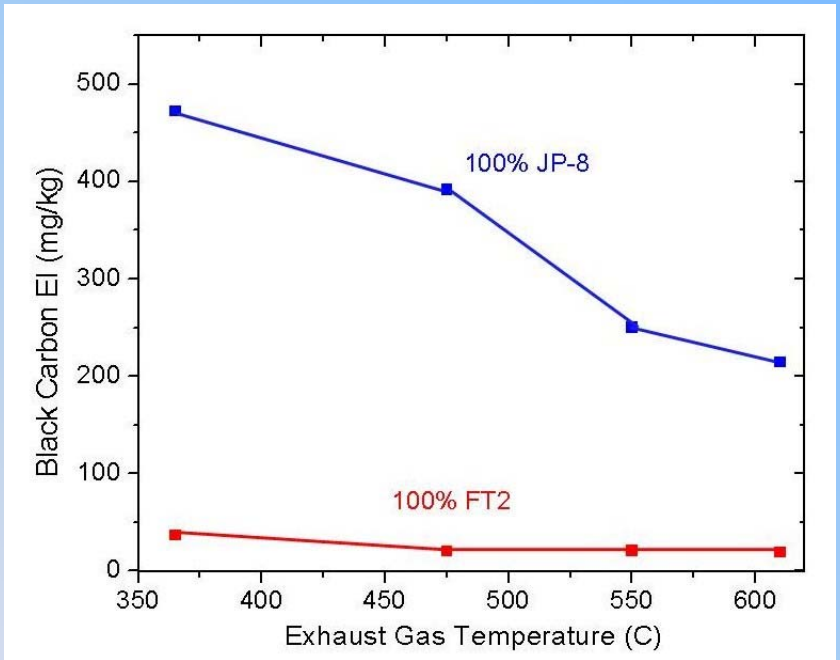


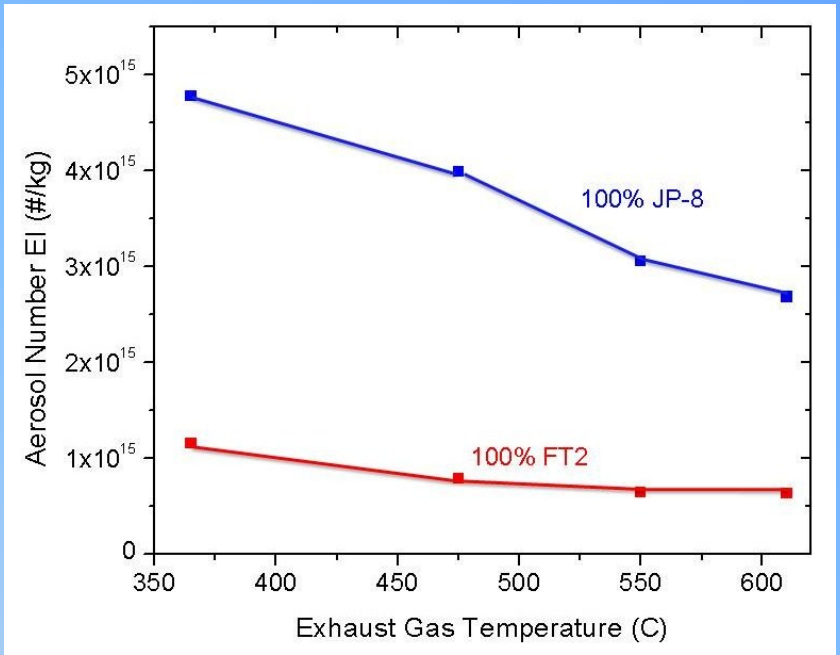
Number emissions 98% lower at idle, 40% at takeoff power Emission reduction disproportionate to fraction of FT fuel in blend

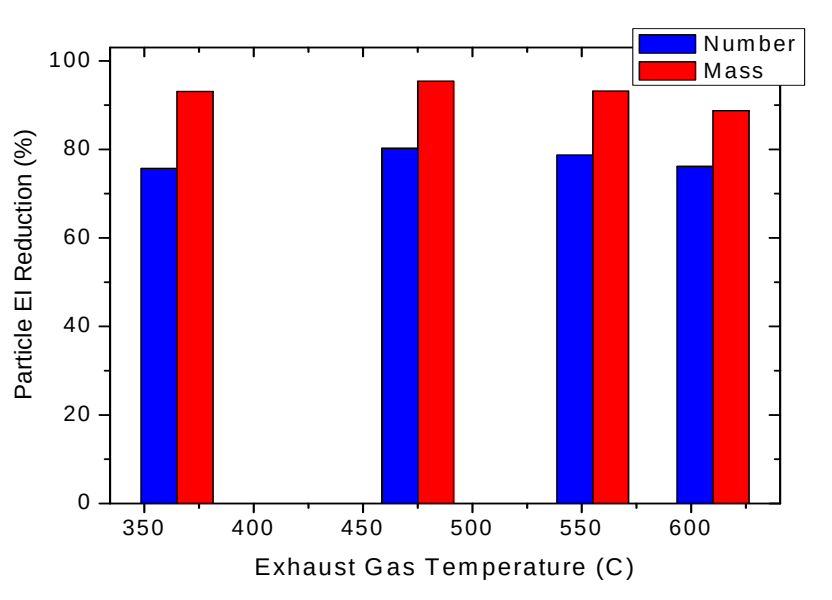


Mass emissions 80% lower at idle, 50% at takeoff power Blended fuel reduced mass emissions by >50% at all powers.

FT Fuel Greatly Reduces APU Particle Emissions







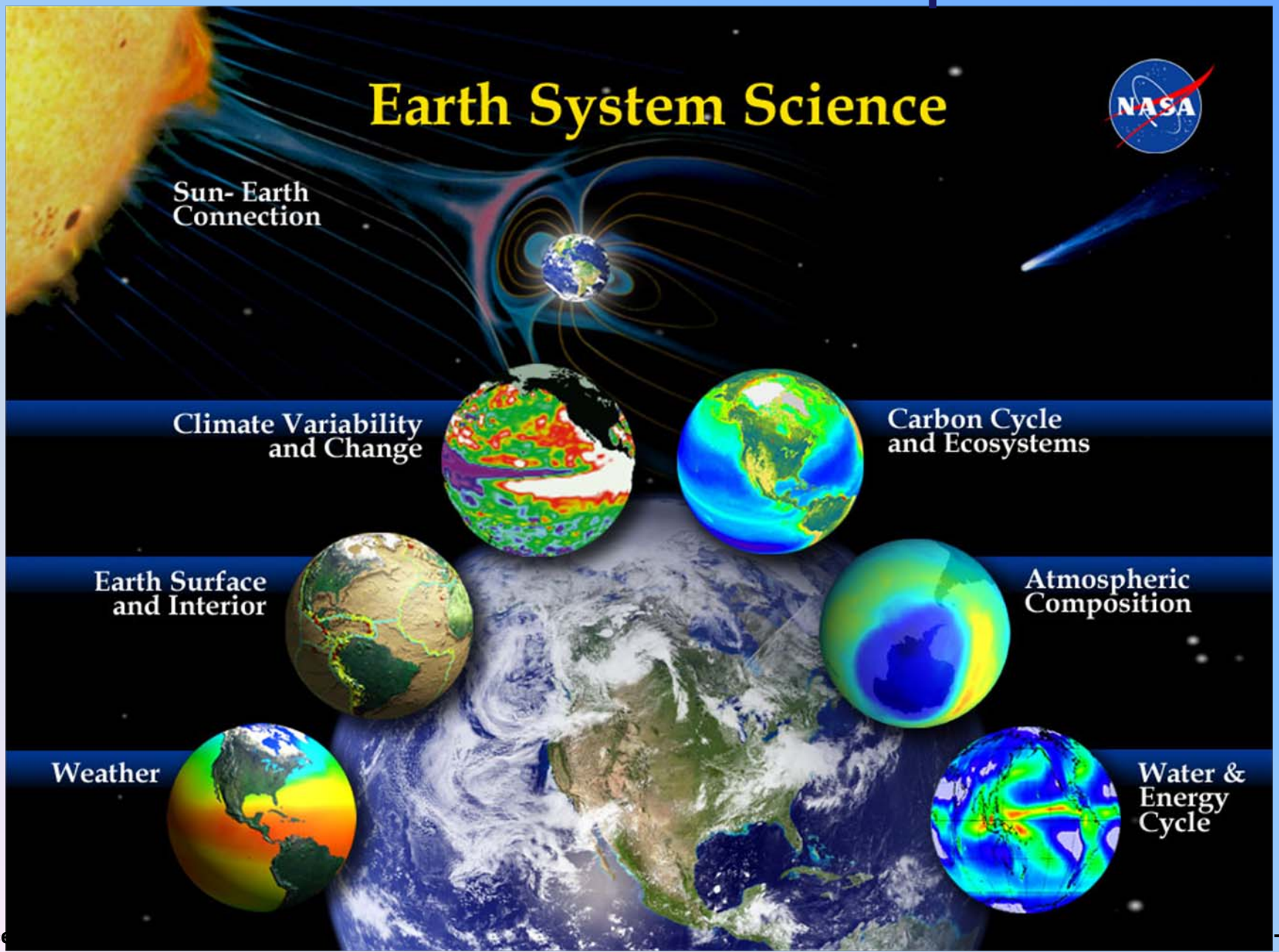
APU emits 25x more black carbon per kg fuel at idle than an aircraft engine

Mass emissions 90% lower when burning FT fuel

Aircraft just one of many sources of pollution

NASA's job is to understand the entire Earth System and how ALL human activities affect it

NASA Science provides the context for understanding Aviation chemical/climate impacts



Atmospheric Composition funds Individual Investigators

Component R&A Programs:

Upper Atmosphere Research Program (UARP)
Ozone recovery; UT & stratosphere chemical/ physical process; Chemistry-Climate connections;

Radiation Sciences Program (RSP)
Climate impacts of aerosols and clouds –aerosol morphology & chemistry, convective transport, etc.

Tropospheric Chemistry Program (TCP)
Transport and transformation of gases and aerosols influencing Climate and Air Quality

Atmospheric Chemistry Modeling and Analysis Program (ACMAP)
Data analysis and modeling integrating satellite, aircraft, balloon, and ground-based observations

Observational Assets:

Satellites: Aura, CALIPSO, CloudSat, Terra, Aqua, Parasol, ENVISAT, ACE, EUMetSat, OCO, Glory, NPP, GOSAT

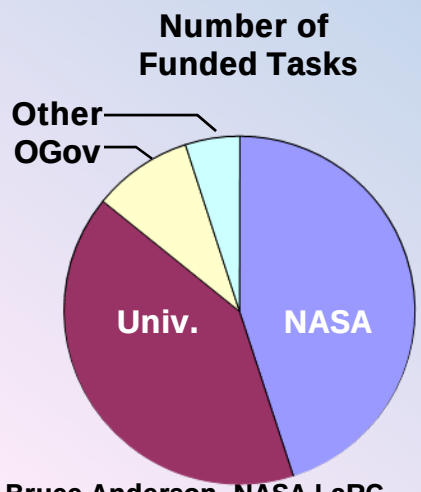
Aircraft: DC-8, WB-57F, ER-2, P-3B, UAVs, other agency and international aircraft

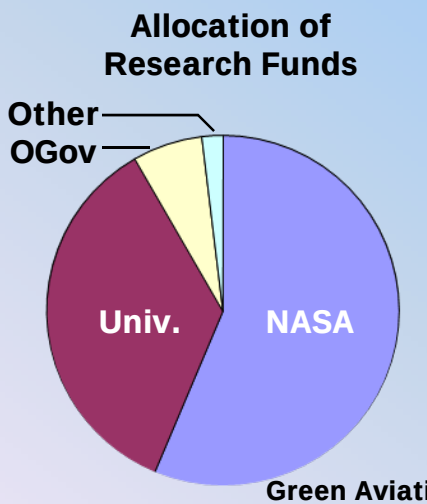
Balloons: High-Altitude/Heavy-Lift for remote sensing, in situ soundings for ozone, T, H2O, aerosols

Ground: AGAGE, NDAAC, AERONET, MPLNet, NATIVE, SMART-COMMIT, other agency networks

Other Investments: Laboratory studies, model and instrument development

FY07 R&A Budget: $36.5M for ~250 tasks





Key Roles played by NASA centers and non-NASA organizations

	GSFC	LaRC	ARC	MSFC	JSC	WFF	DRFC	JPL	non-NASA
Satellite Mgmt.	X	X						X	
Satellite Data	X	X						X	X
Suborbital Mgmt.					X	X	X		X
Suborbital Data	X	X	X	X		X		X	X
Field Support			X						
Science Leadership	X	X	X					X	X
Modeling	X	X	X					X	X
Laboratory Studies		X	X					X	X

Current SMD Activities Related to Green Aviation

NASA Science Mission Directorate

- Applied Sciences Program ROSES DECISION NRA's
- Science Research Program NRA's
  - Model simulation of ozone change from NOx emission
  - Climatology of Contrails and Cirrus for Climate Change Studies

Langley Science Directorate Efforts

- Support of NASA Fundamental Aeronautics Environmental Research Program
- Support FAA's Aviation Emissions Road-mapping Effort
- Participation as subject matter experts in NextGen JPDO Environmental Working Group
- Collaboration with FAA Aviation Climate Change Research Initiative (ACCRI)

Improving Climatology of Contrails and Cirrus for Climate Change Studies

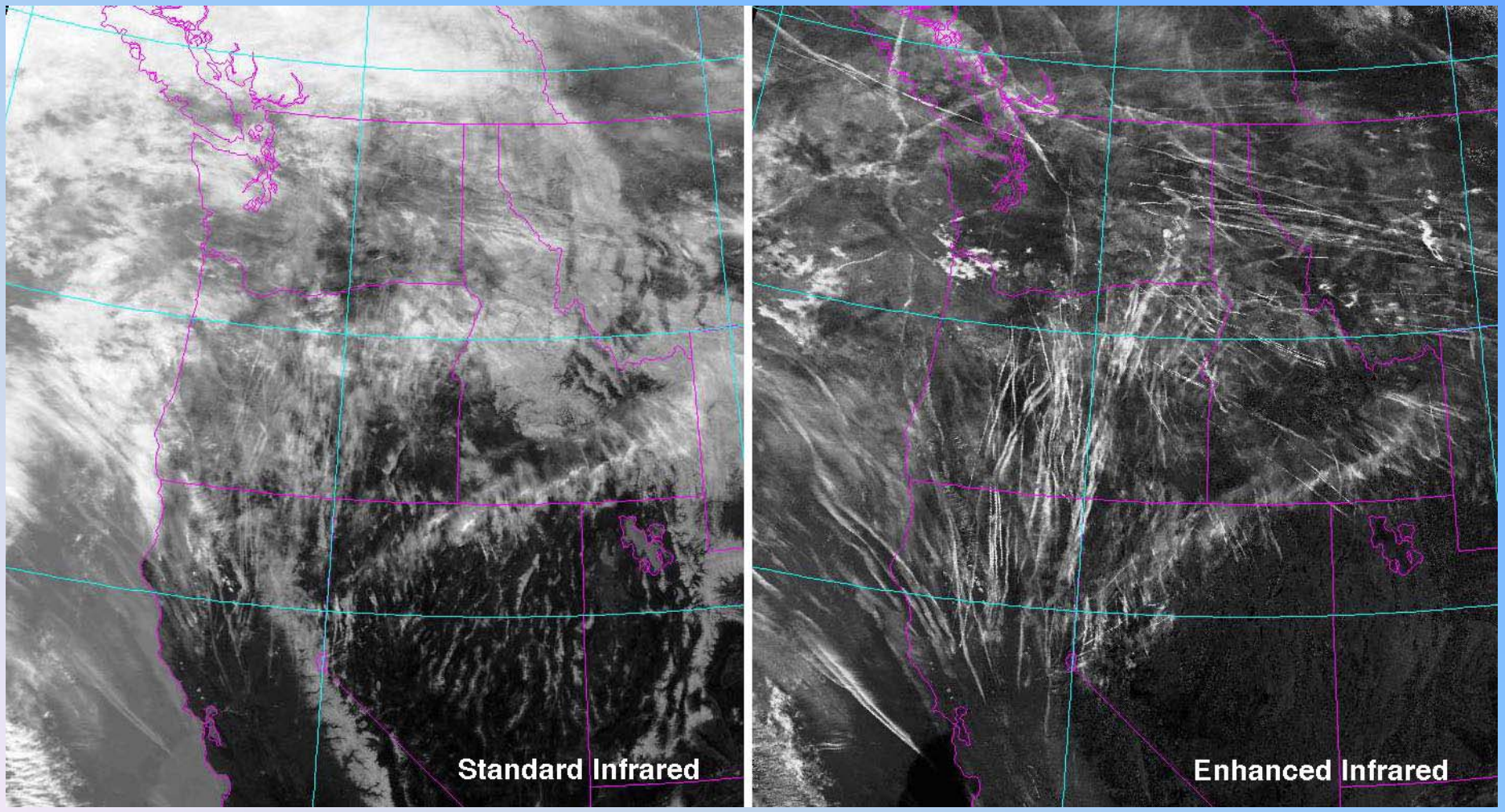
- Determine coverage of contrails and contrail-induced cirrus clouds over North America for a multi-year period using high-resolution satellite data

- Measure the optical properties of the detected contrails
  - ice water path, crystal size, optical depth

- Estimate their climate impact
  - compute shortwave & longwave radiative forcing

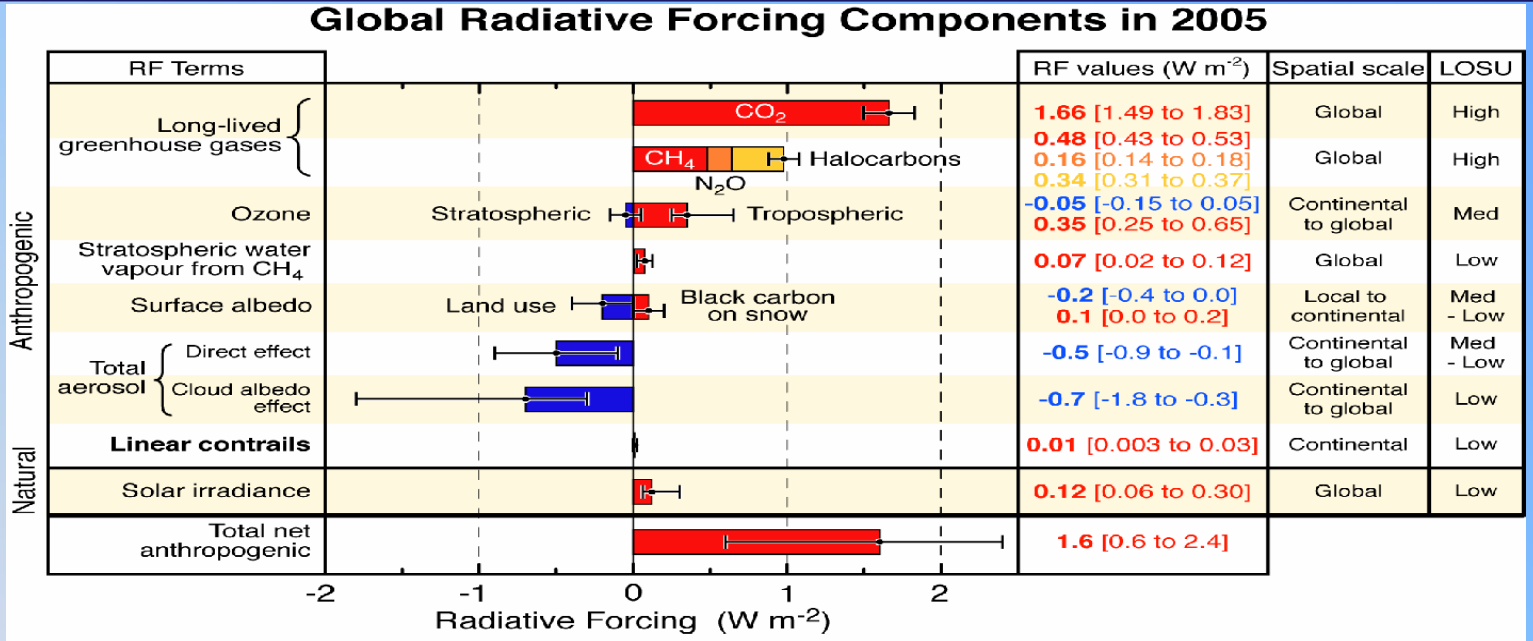
Pat Minnis group, NASA LaRC

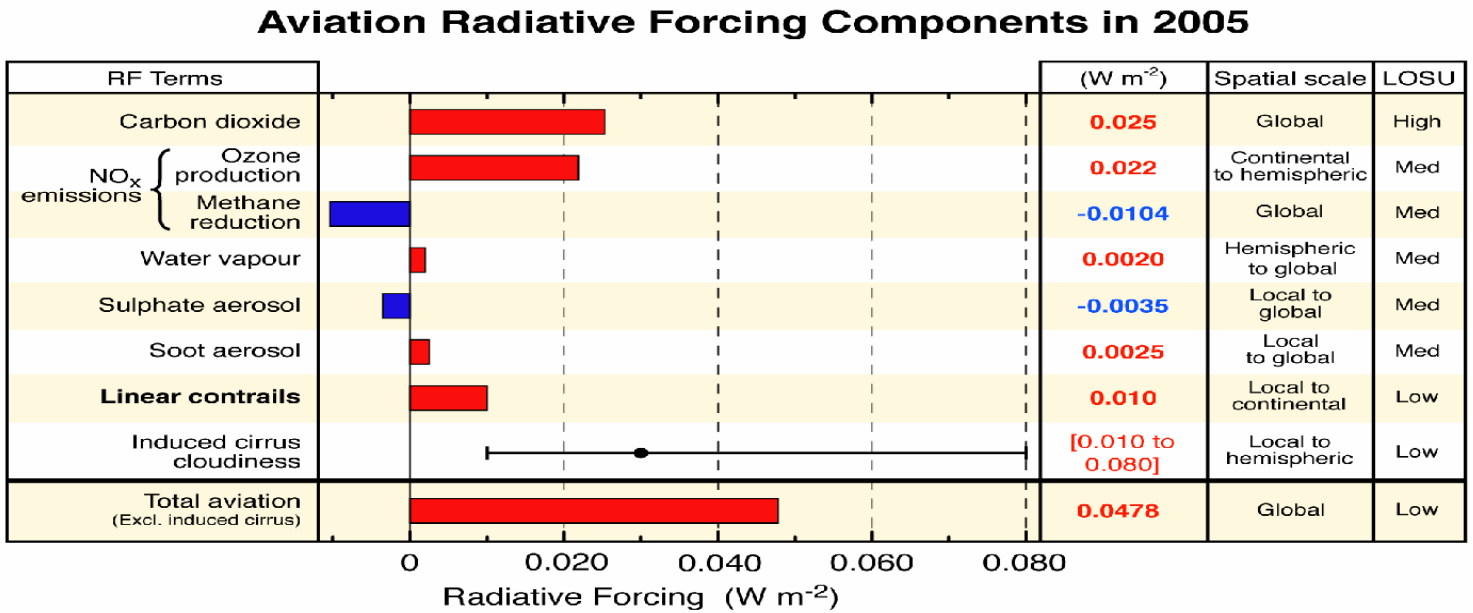
Infrared Images from 1-km *NOAA-17* AVHRR
17 March 2004, Western US



SMD is also funding an aviation/ozone modeling study and will include aviation topics in ROSES-2010

Punchline: Aviation a Small Fraction of the Climate Problem





Questions?