NASA Low-Emissions Research

(And Things Related to Alternative Fuels)

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CRC Aviation Meeting

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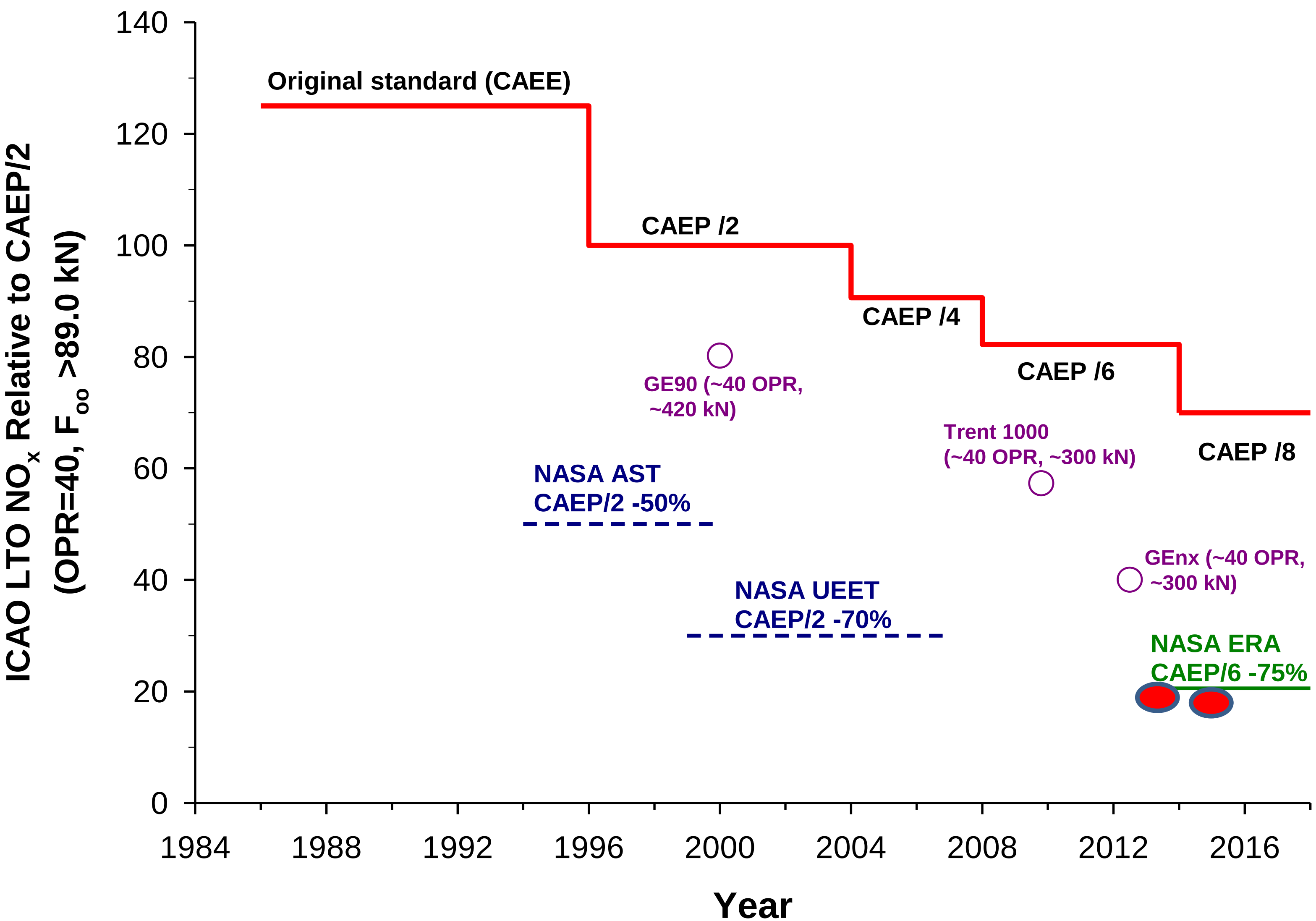
Contents

- Current work
  - ERA low-NOx fuel-flexible combustors Finished
  - NJFCP LBO test
  - ACCESSS II Finished
  - APU test
  - MIT upper atmosphere modeling
- Coming up…
  - Woodward N+3
  - Direct particulate extraction from combustor

~50% NOx Reduction Every 15 Years



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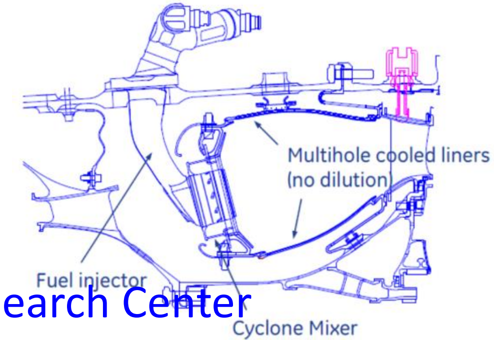
Courtesy of Changlie Wey

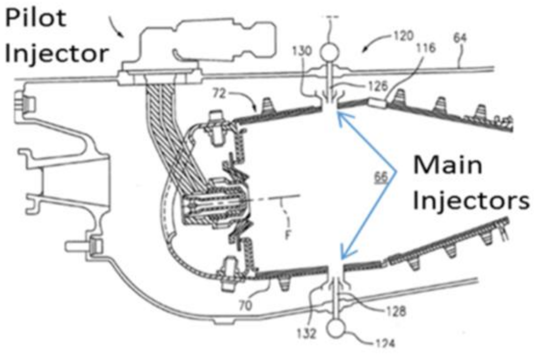
ERA Fuel-Flexible Low-Emissions Combustors

-75% CAEP /6 LTO NOx, 50/50 JP/Rentech blend

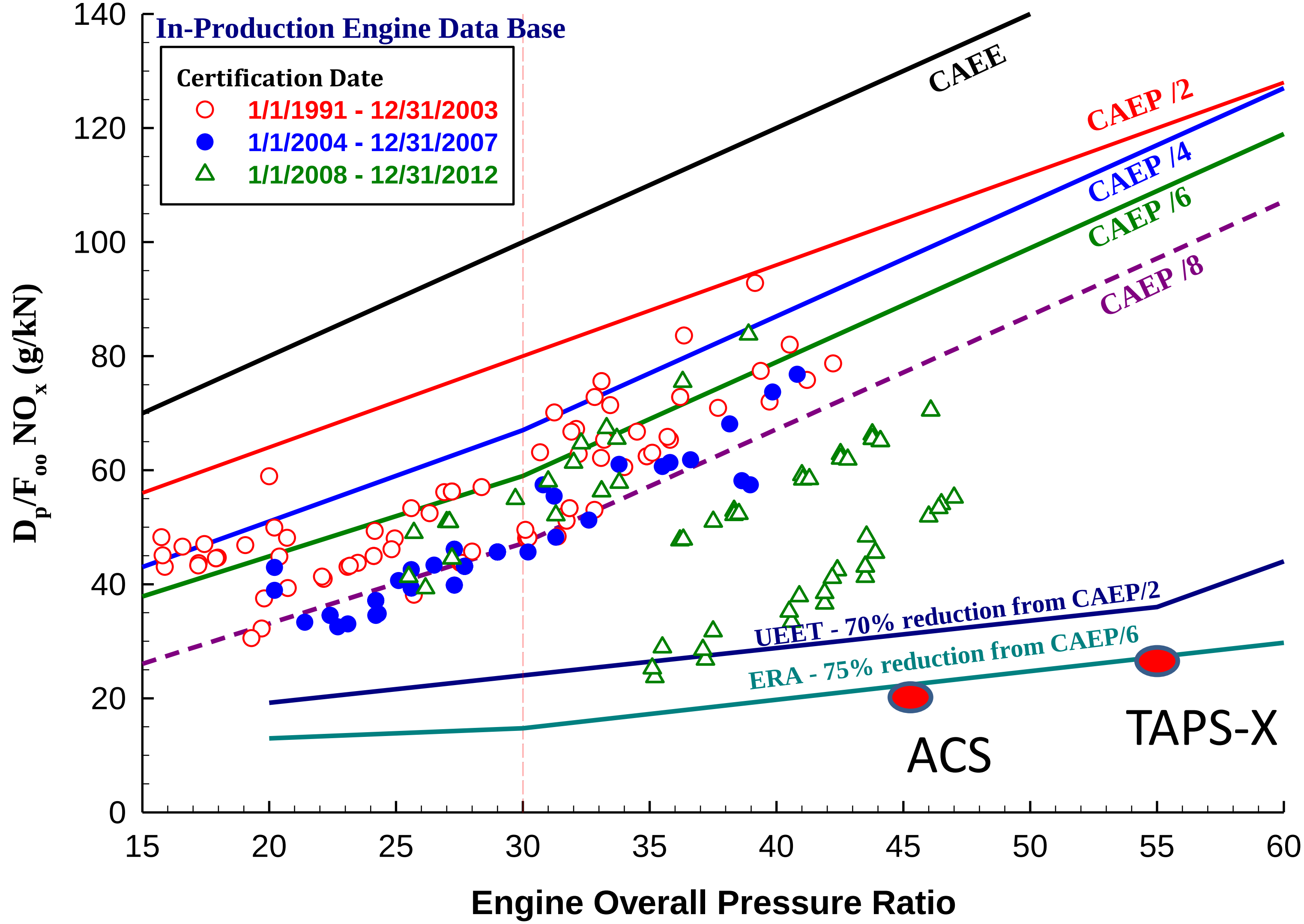
GE TAPS-X 5-cup Sector Combustor



P&W ACS Annular Combustor



ERA LTO NOx Reduction Goal Met!



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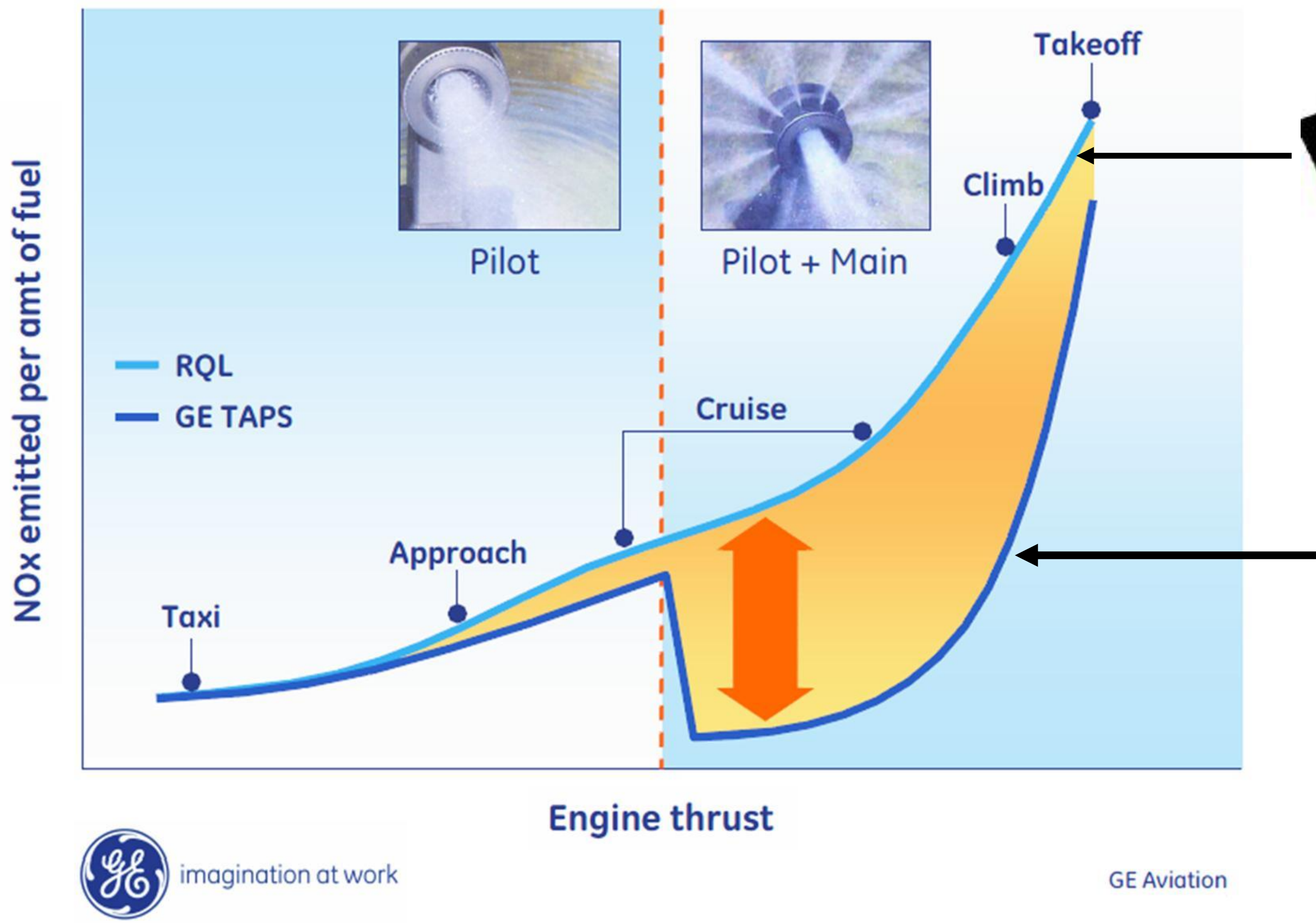
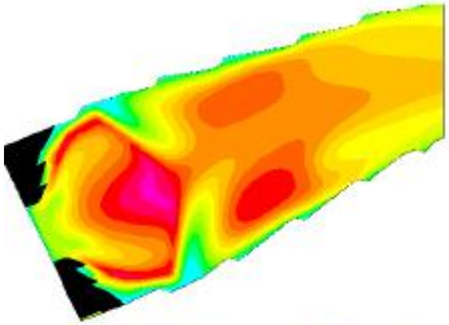
Courtesy of Changlie Wey

Superior Cruise-Level Emissions Advantage

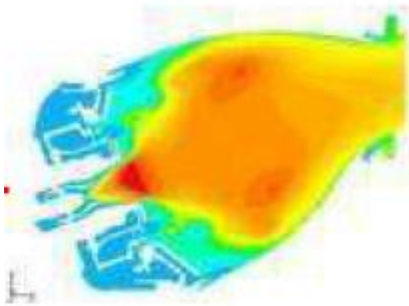
From Staged Partially-Premixed Lean-Burn Combustor

NOx flight cycle comparison (GE TAPS vs. traditional RQL combustor)





Traditional Rich Burn (RQL)



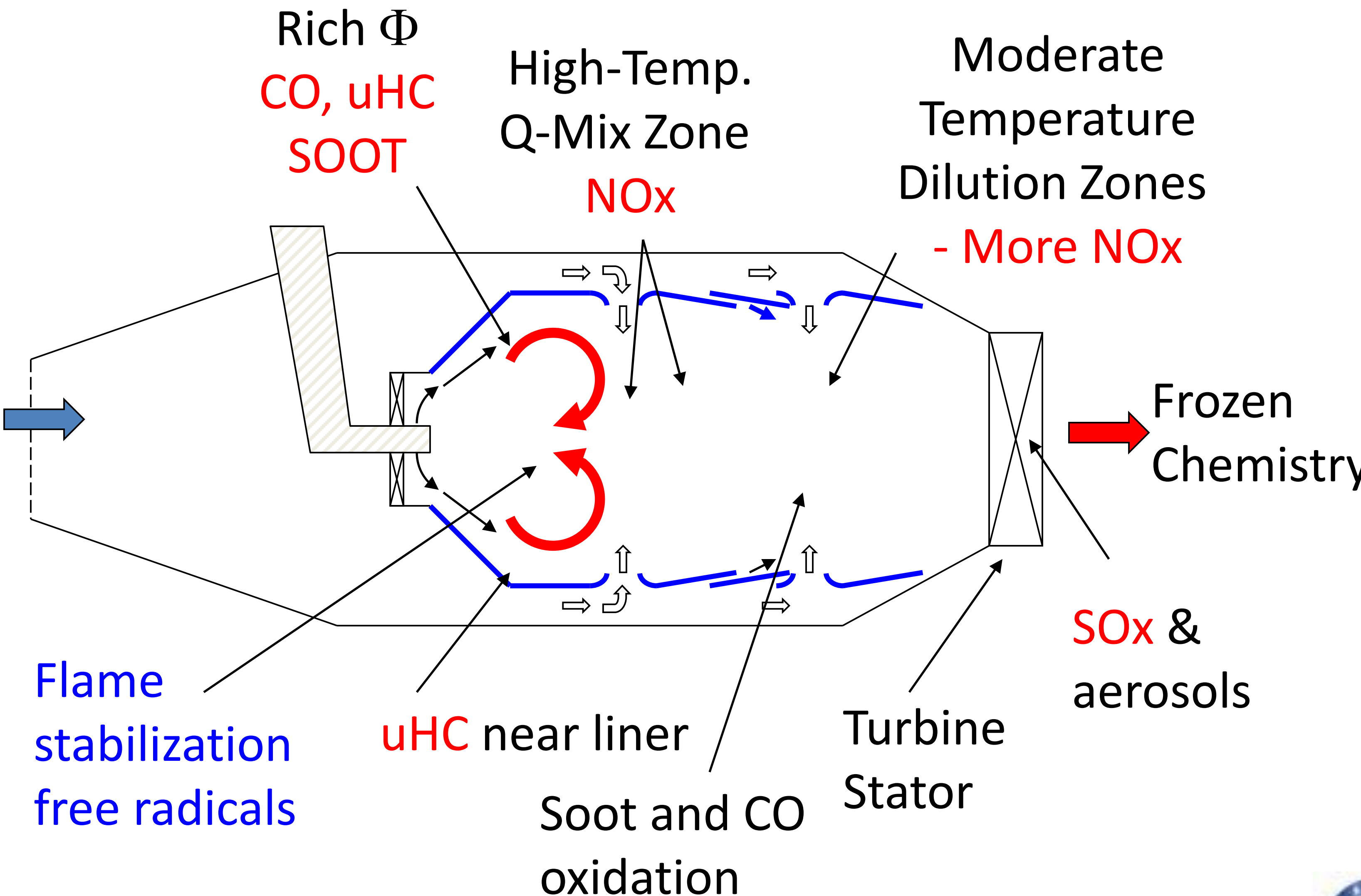
Lean Burn

Courtesy GE Aviation

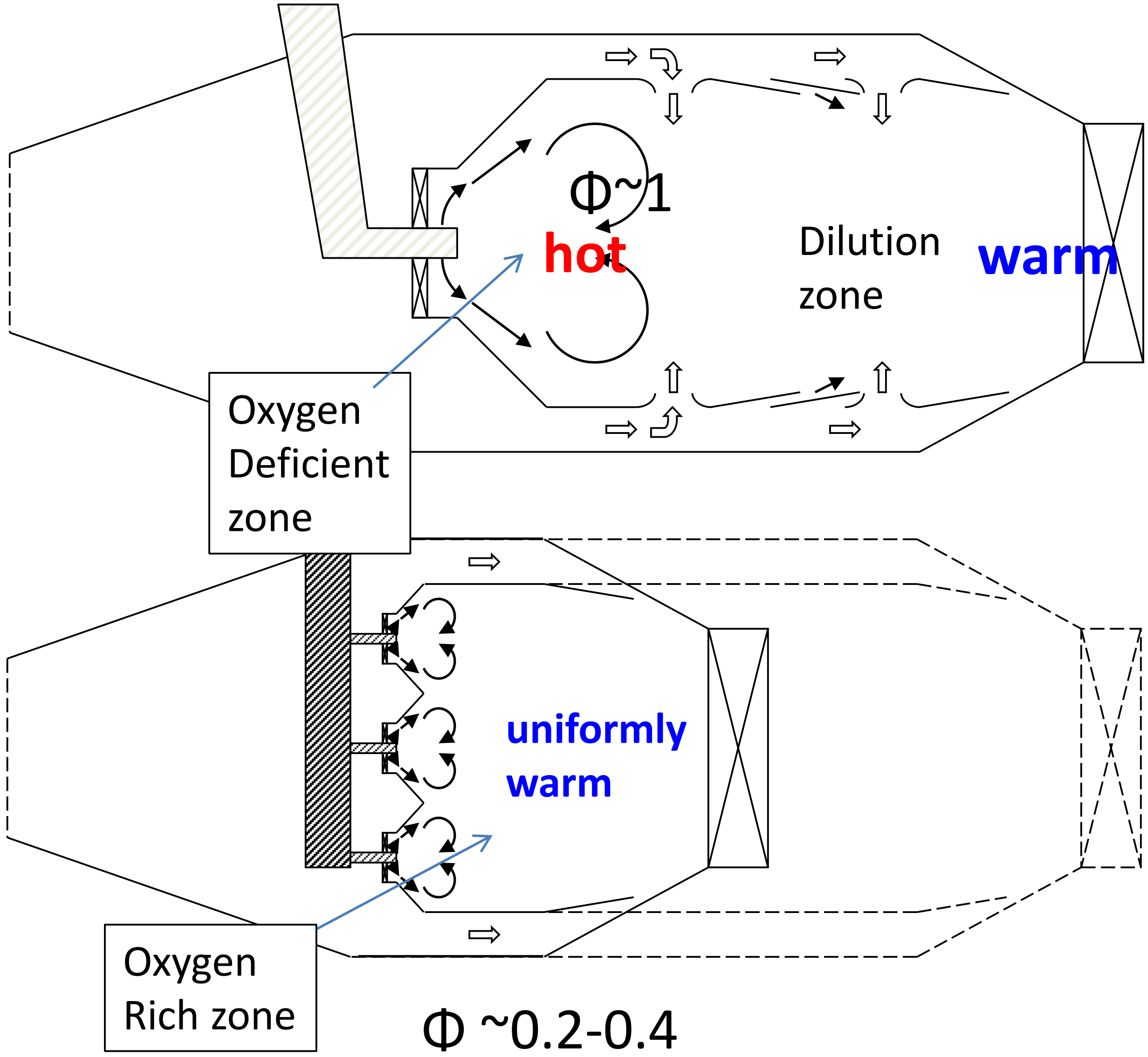
Fuel Composition Effect on Lean-blowout (LBO) and Ignition Characteristics in a Lean-Burn Combustor

Q: Why test fuels in a Lean-Burn Combustor?

Where Do Pollutants Come From?



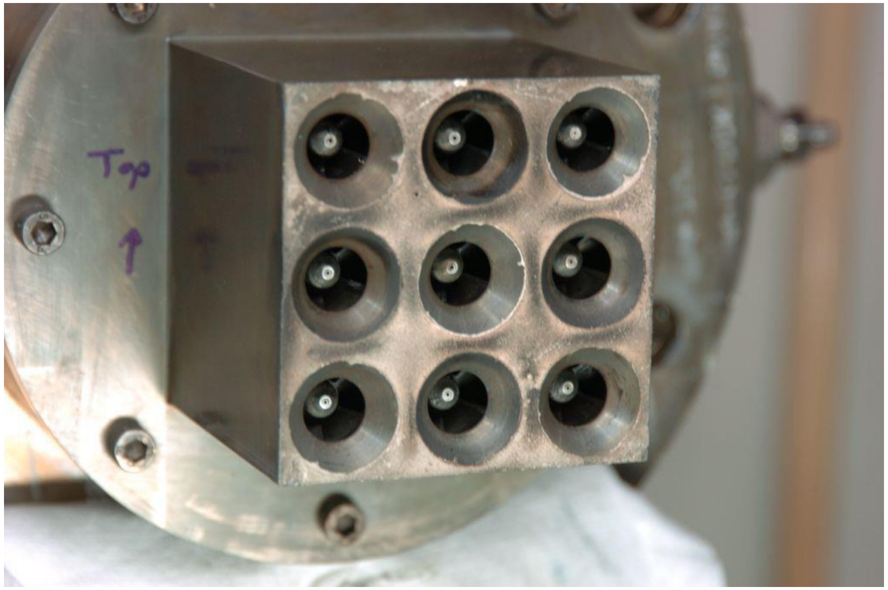
Lean-Burn: A Simpler Platform for Testing Fuels



Complex aerodynamic & chemical processes

- Makes little soot
- Very limited residence time
- Fast F/A mixing
- Ignition delay shows up
- Kinetics rate show up

LBO / Ignition of A-2 (JP) vs C-1 (ATJ-IP, 2 comp.)
_Nation Jet Fuel Combustion Program

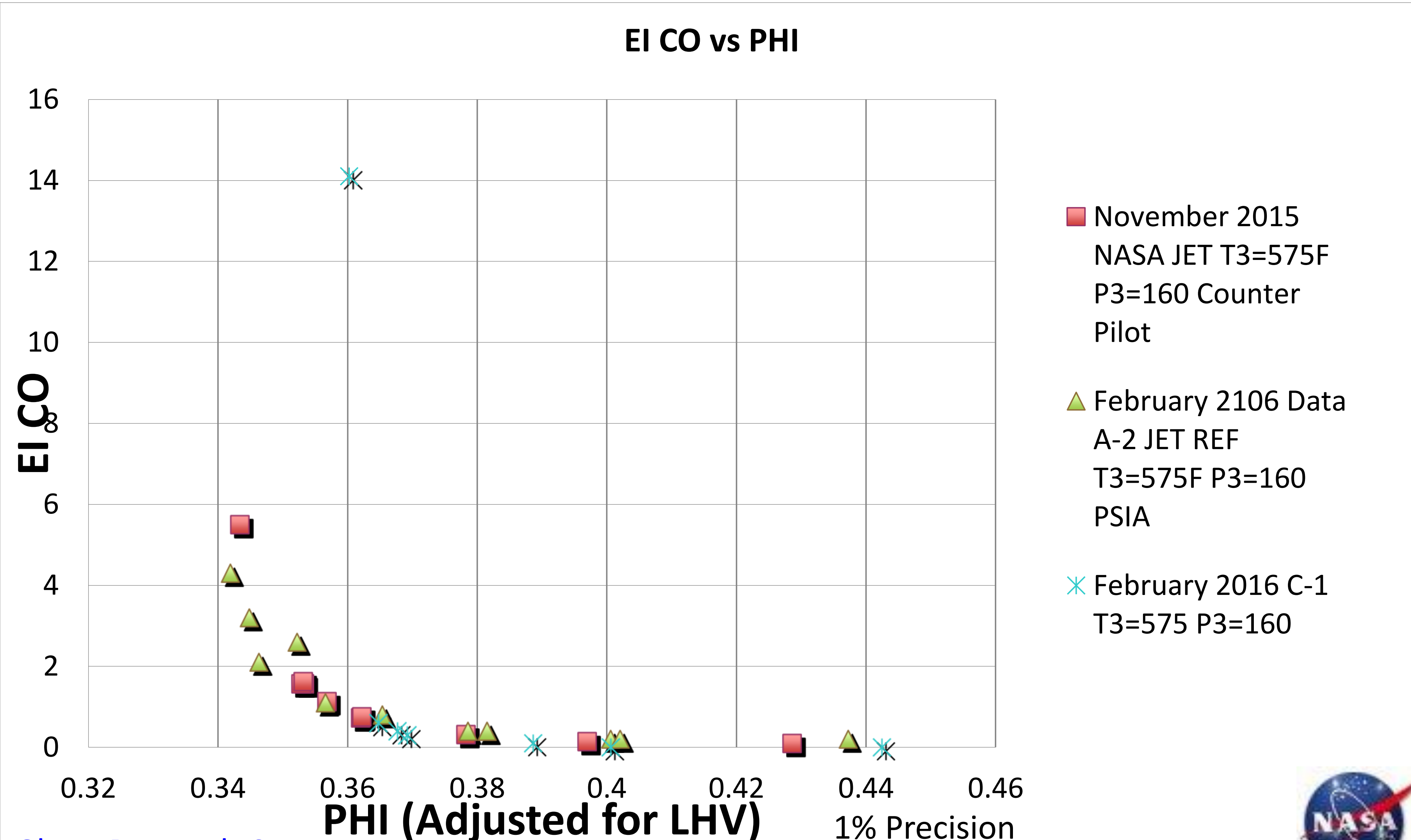


- 9-point Lean Direct Injection
- 1-inch spacing
- 4 Fueling stages
- Center-injector pilot
- Flow throttling boundary conditioning

JP JP/SPK SPK

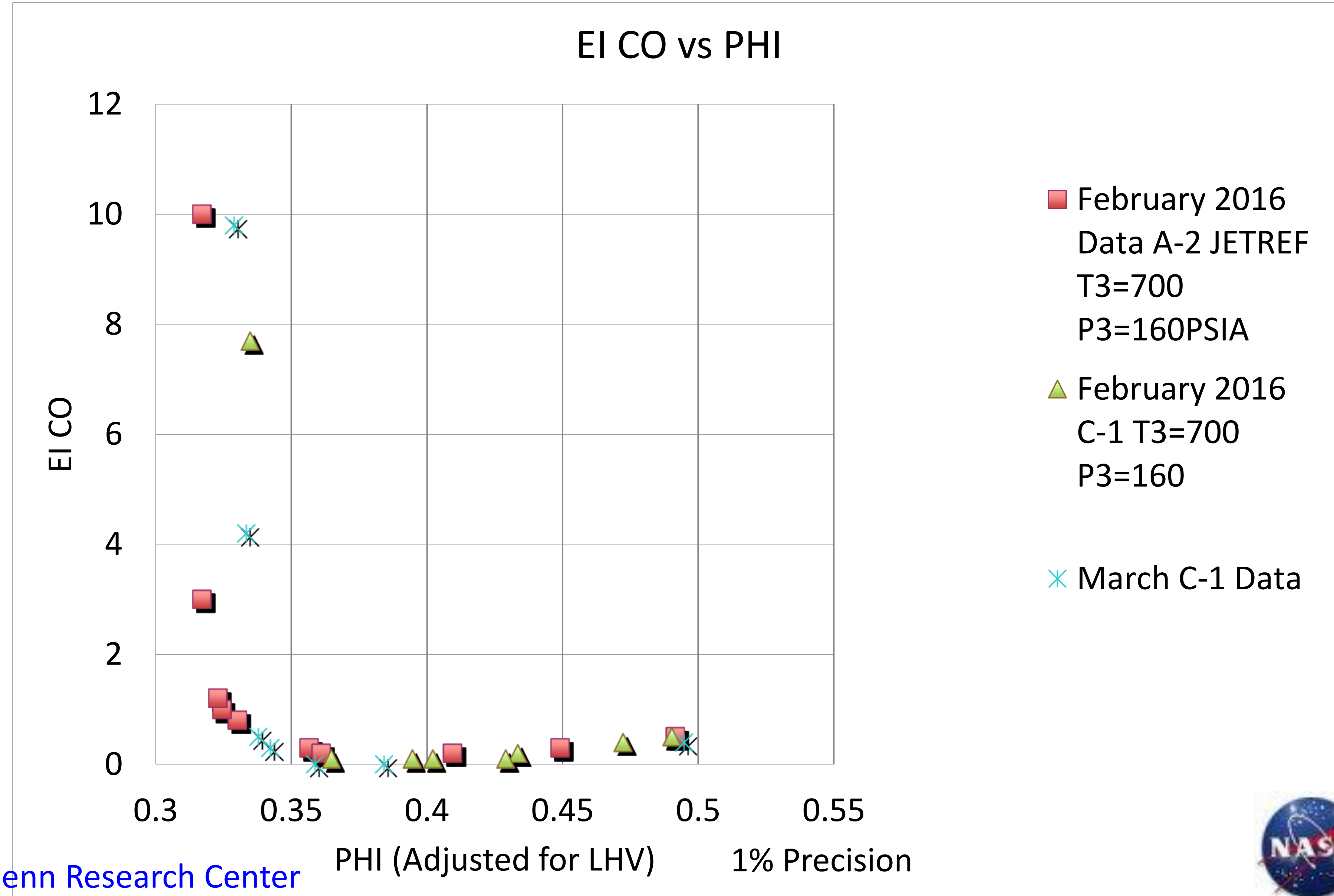
CO Key Indicator for LBO

A-2 vs C-1 at 575 °F 160 psia



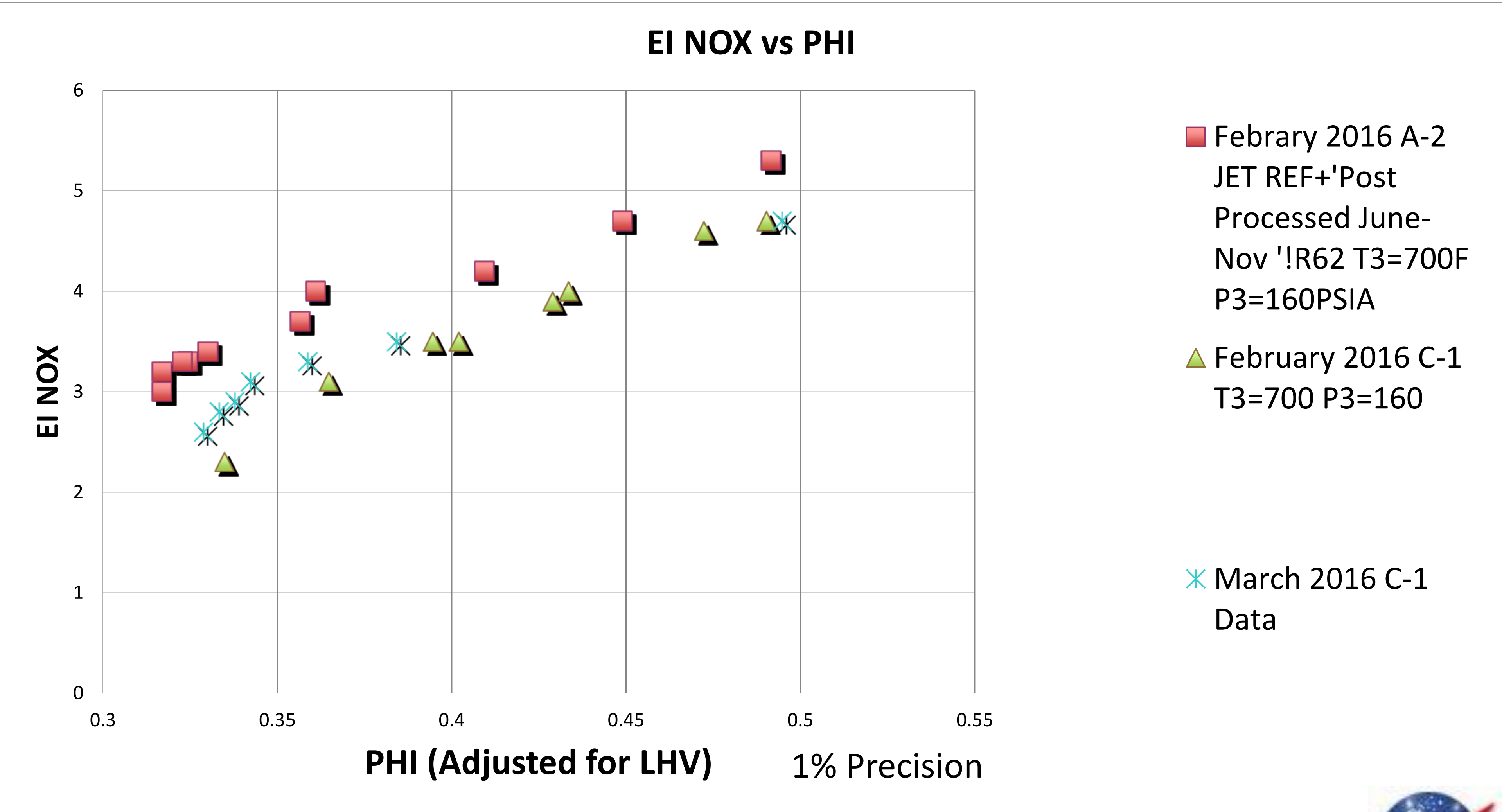
Discernible LBO Difference

Between A-2 and C-1



Discernible NOx Difference

A-2 vs C-1 (ATJ-IP) at T3=700 °F P3=160 psia



National Jet Fuel Combustion Program

A-2 vs. C-1 (GEVO ATJ) in LDI hardware

LBO Adjusted Equivalence Ratio			
P3, psi (bar)	T3,°F (degC)	A-2	C-1
100 (7)	575 (300)	0.362	-
160 (11)	575 (300)	0.342	0.36
160 (11)	700 (370)	0.32	0.33
250 (17)	850 (455)	0.28	0.295

No ignition for C-1 until 1000˚F (absence of light components)

Alternative-Fuel Effect on Contrails and Cruise-Level Emissions
(ACCESS II)

Alternative-Fuel Effects on Contrails and Cruise Emissions (ACCESS)

Bruce Anderson, Project Scientist
Richard Moore, Post-Doctoral Fellow
Lee Thornhill, Data Manager
Edward Winstead, Instrument Manager
Luke Ziemba, AMS; Josh DiGangi, DLH

Greg Slover and Rick Yasky, Project Pilots

ACCESS Sponsored by NASA Fundamental Aeronautics, Fixed-Wing Project

Engine Thrust Varied to Study Power-Dependent Emissions

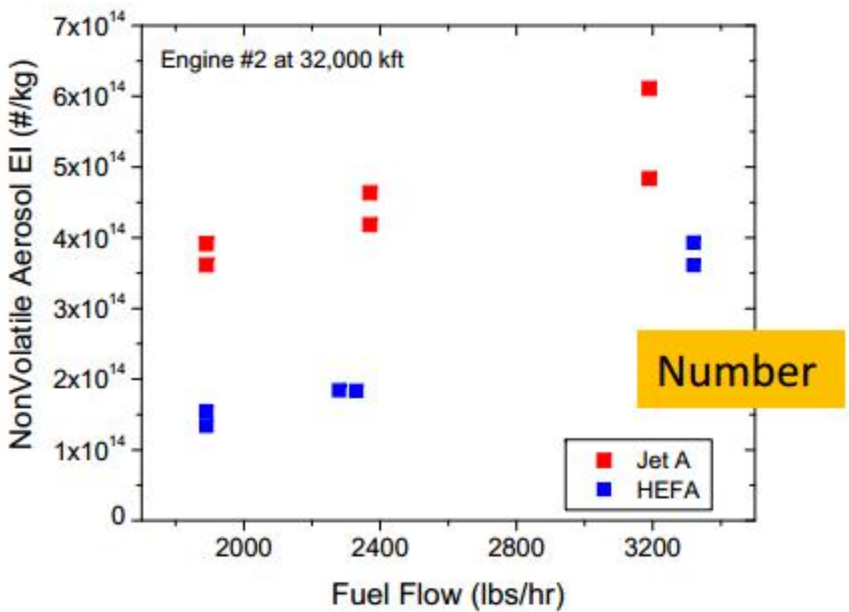
Inboard Engines Idled Back

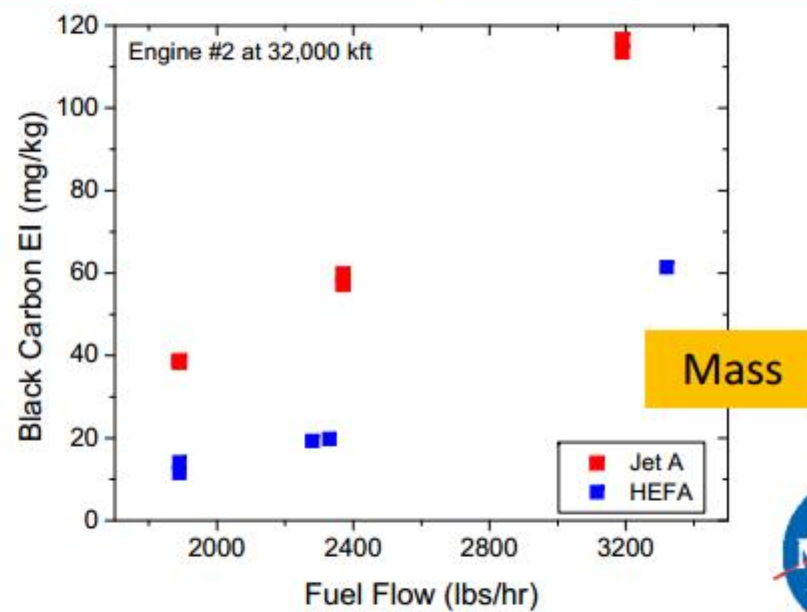
Outboard Engines Idled Back

Varied Engine FF from ~1000 to 3000 lbs/hr, balancing Inboard/Outboard thrust to maintain constant 200 knots IAS

Preliminary Results from ACCESS II Flight Campaign

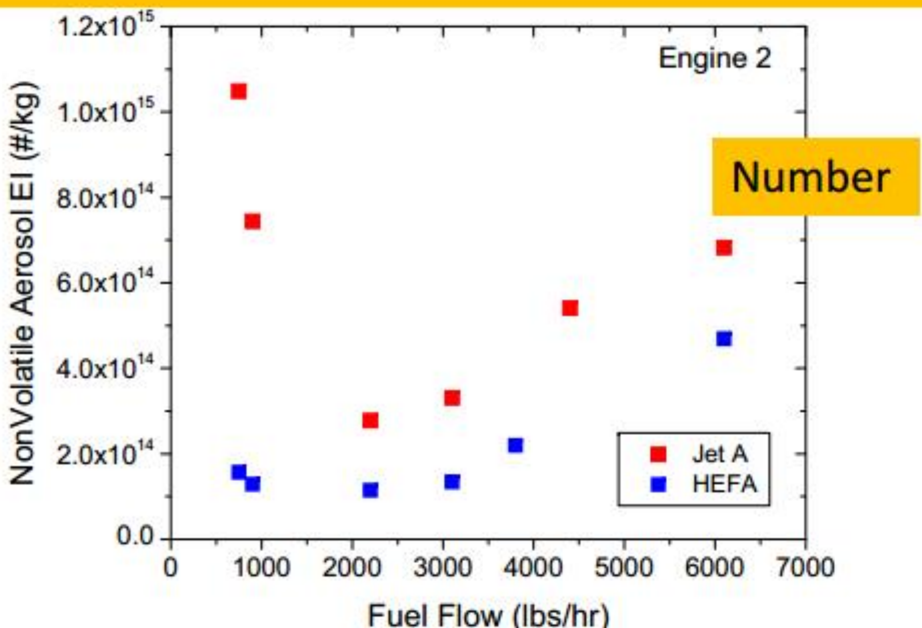
HEFA Blend Reduces Black Carbon Number and Mass Emissions by 30 to 60% at Cruise

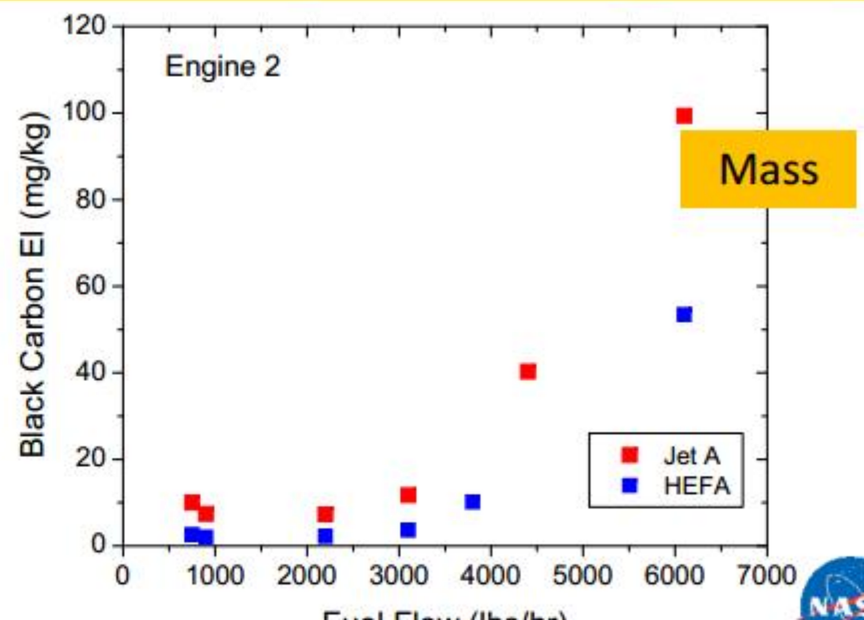




Cruise EIs Consistent with Ground Test Measurements

HEFA Blend Reduces Black Carbon Number and Mass Emissions by 30 to 80% during Ground Op





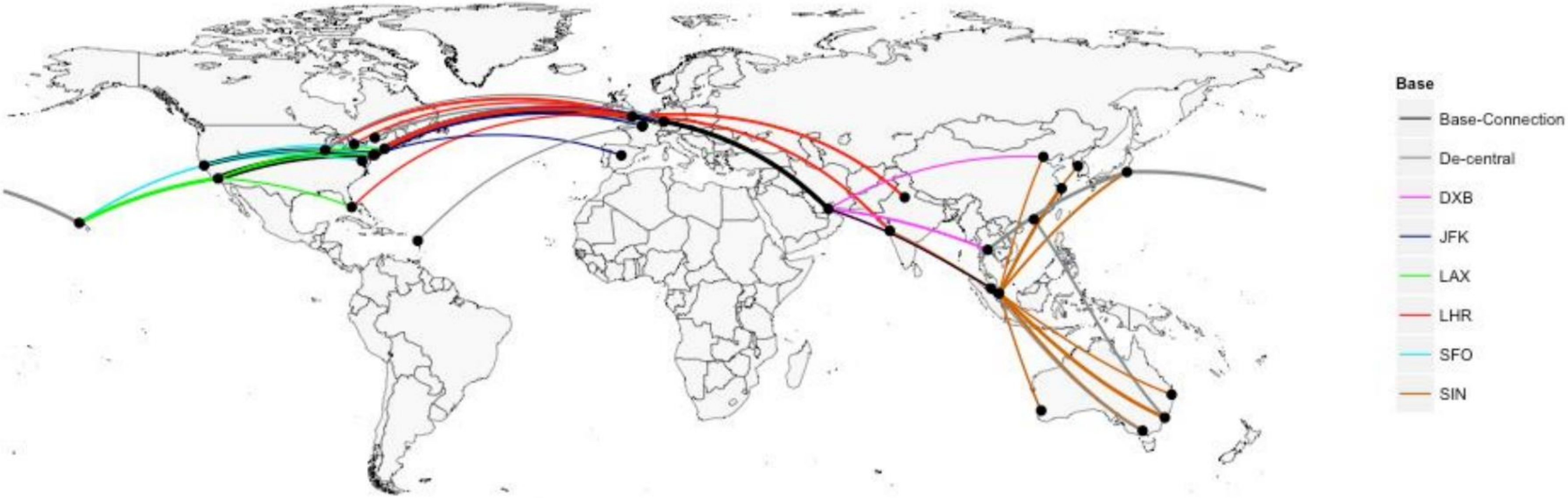
Alt-Fuel GRC APU Test

- Soot measurement (with Langley truck)
- Contrail formation mechanism in altitude chamber (Controlled environment)

Global Environmental Impact of Supersonic Cruise Aircraft in Atmosphere

Steven Barrett
Laboratory for Aviation and the Environment
MIT
2014-2018

SST Routing Replacement Assessment



Effect of SST Fleet on Ozone Change

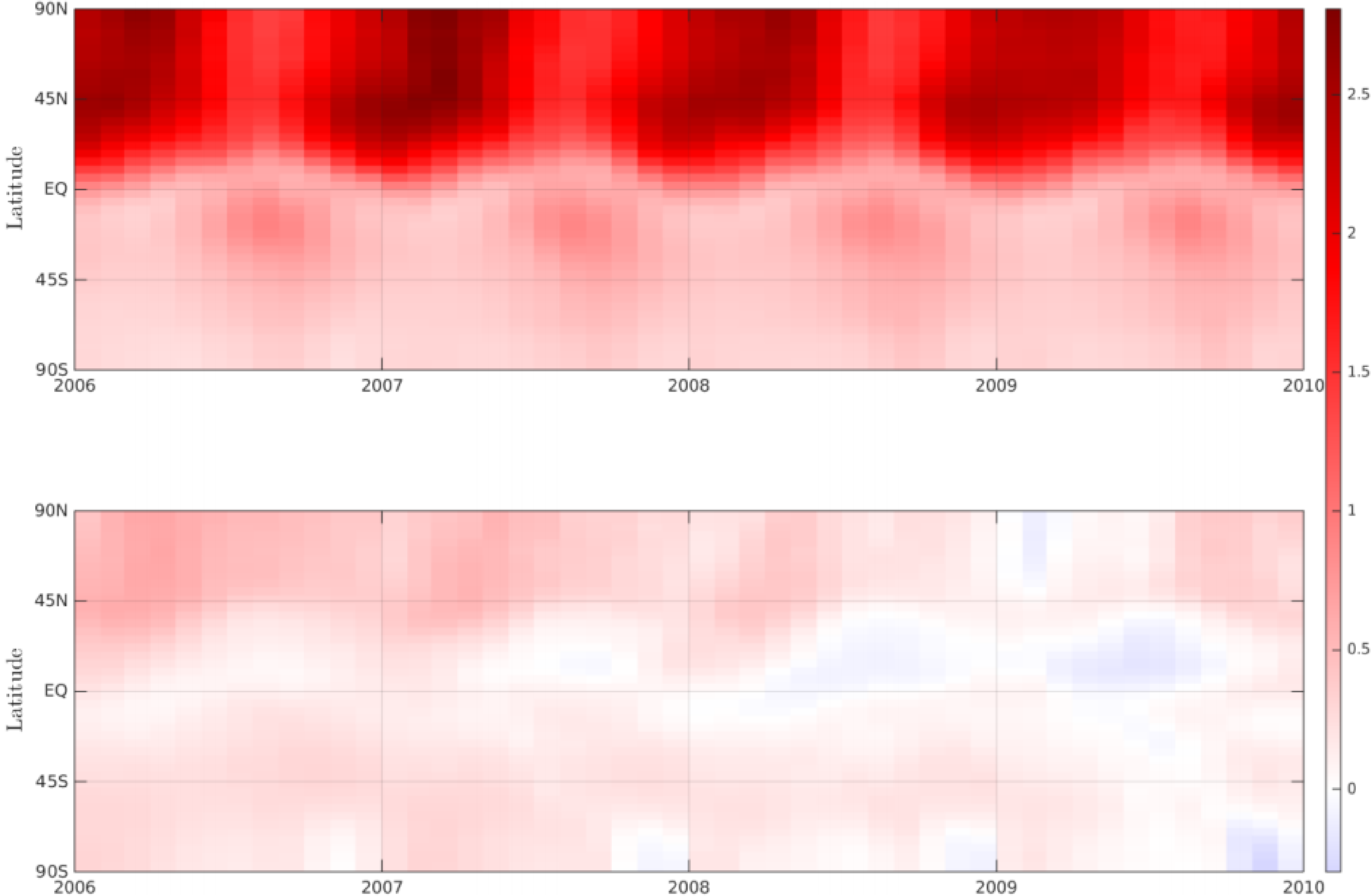


Figure 7.2. Column ozone change due to subsonic (top) and supersonic (bottom) aviation emissions

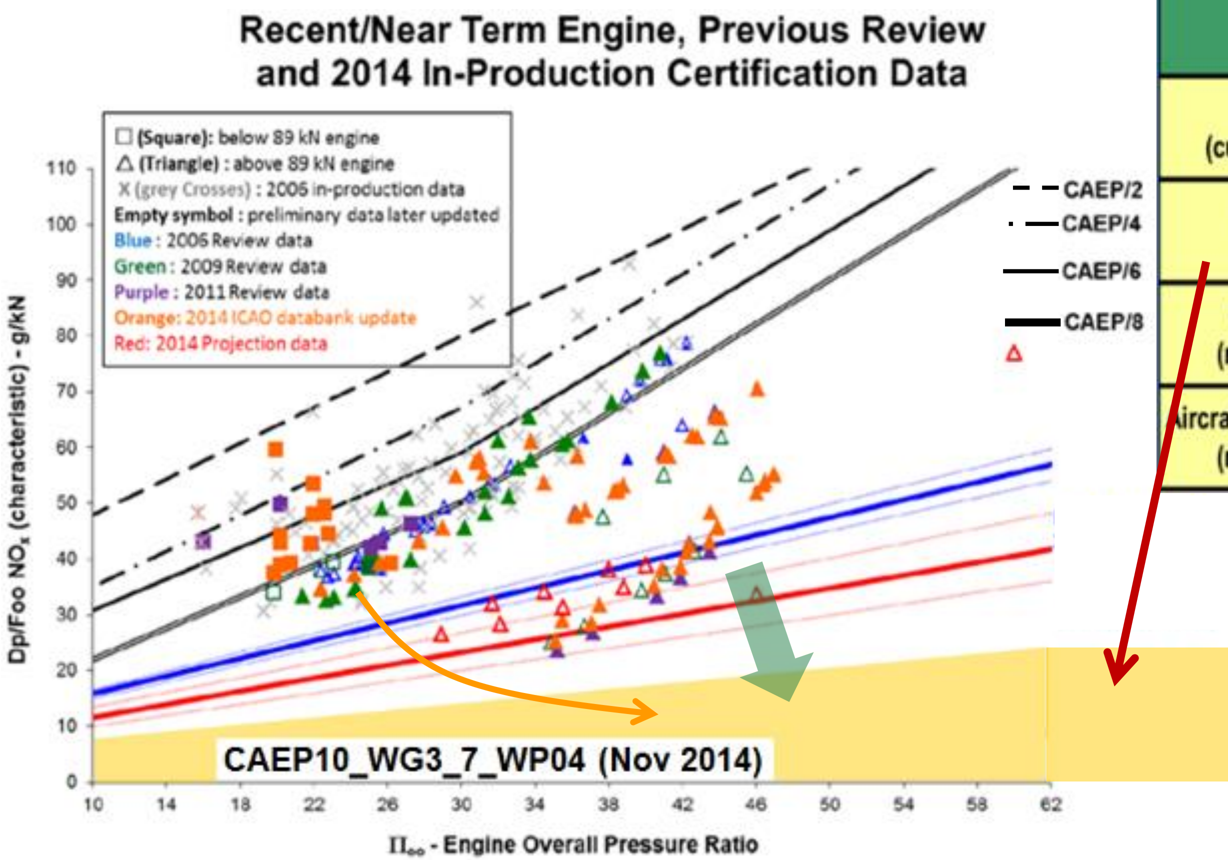
Coming Up…

N+3 Small Core (AATT)

and Extractive PM Measurement

Technological Challenges for N+3 Small Core, Fuel- Flexible Combustors (AATT)

Need to overcome trend for NOx to increase with OPR ↑



TECHNOLOGY BENEFITS*	N+3 (2025)
Noise (cum margin rel. to Stage 4)	-52 dB
LTO NOx Emissions (rel. to CAEP 6)	-80%
Cruise NOx Emissions (rel. to 2005 best in class)	-80%
Aircraft Fuel/Energy Consumption‡ (rel. to 2005 best in class)	-60%

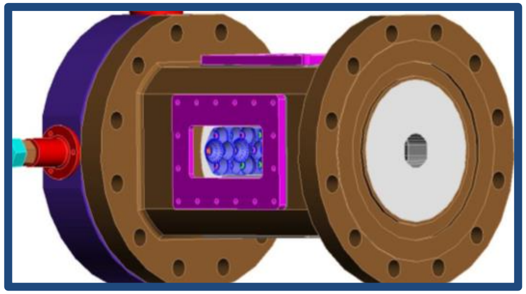
Need to support high efficiency goal:
- high OPR
- high BPR (small core)

This page does not contain any export controlled technical data.

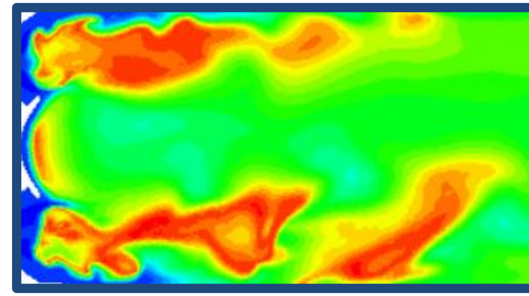
Space Act Agreement (SAA)
Woodward, FST

Objective: Develop a lean direct injection (LDI) combustor for a small-core N+3 engine what will reduce NOx emissions by 80% wrt CAEP/6.

Small Core N+3 SV-LDI 3-cup hardware in flame-tube (TRL 3)

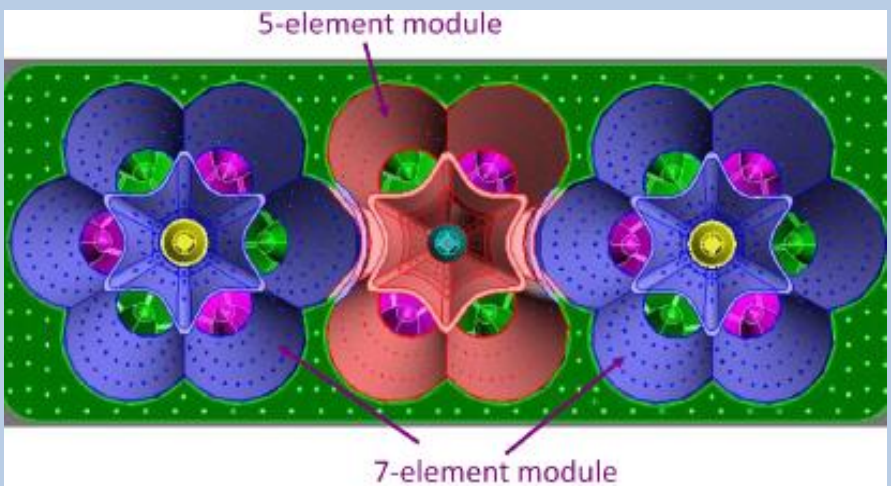


Recent CFD Flame Temperature Results



Small Core N+3 SV-LDI

N+3 Dome, Three Cups



N+3 Fuel Stem

Particulate Measurement from Combustor Direct Extraction

- Early combustor design-life PM assessment
- Assess viability of ground-to-altitude emissions level extrapolation
  – Q: Is E31 (ground PM) measurement useful predictor of altitude PM?
- Develop repeatable process to drop pressure from 250 psi (16 bar) to ambient
- Lean-burn PM peaking diam. ~25-30 nm

For More Info…

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