Fuel and Combustor Concerns for Future Commercial Combustors

Clarence T. Chang
Engine Combustion Branch
NASA Glenn Research Center
Cleveland, Ohio, USA

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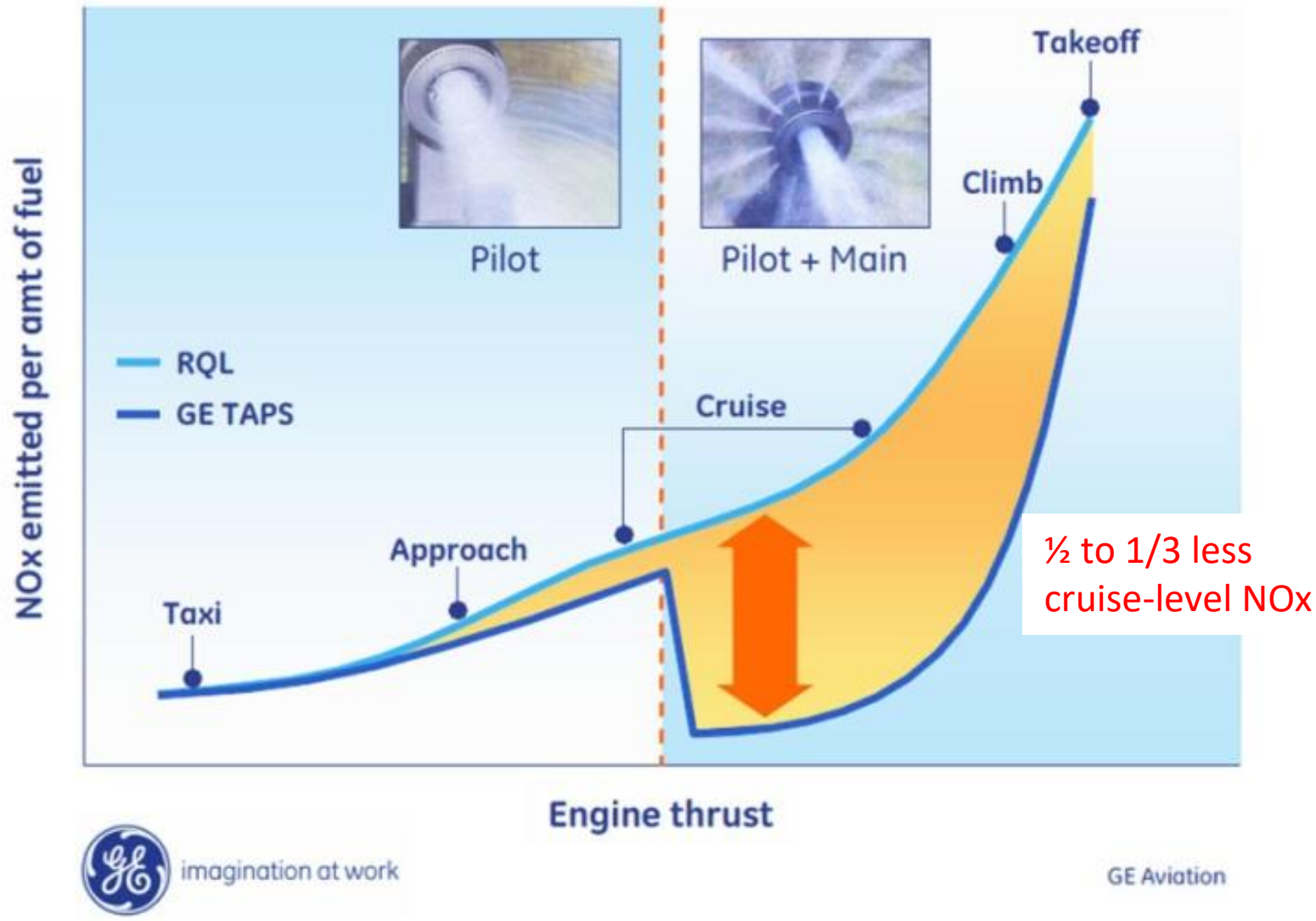
Points to Make

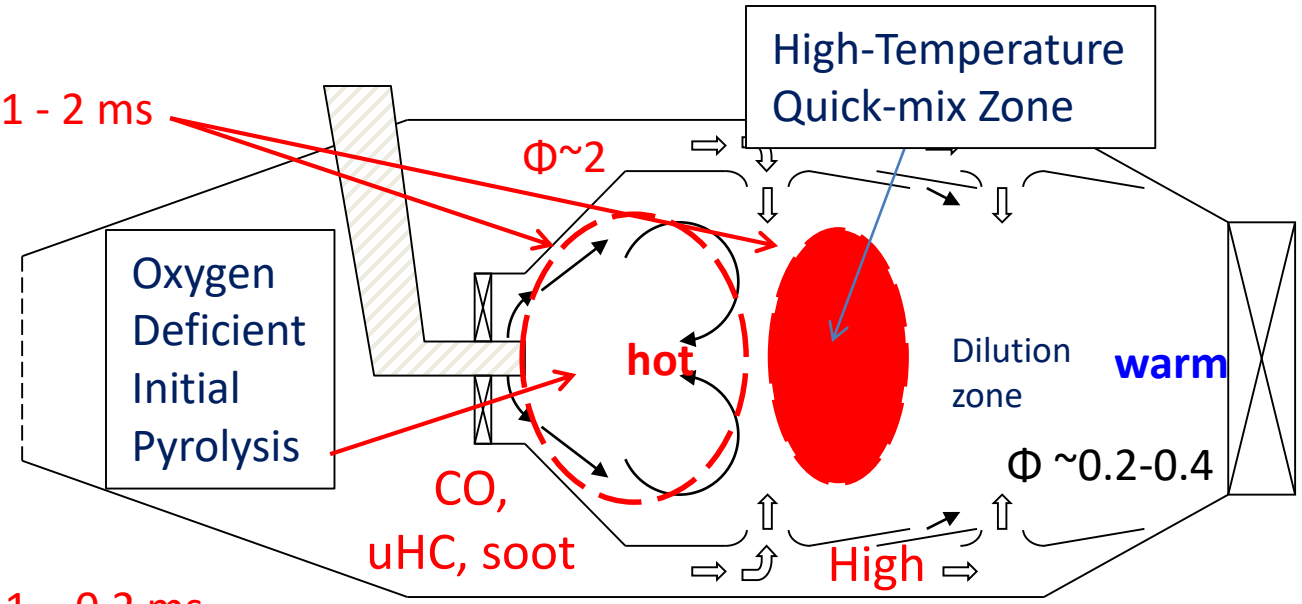
- Lean-burn for future commercial transports
- Lean-burn dependent upon fast fuel-air mixing
- Engine OPR limits lean-burn strategy
- Branch-chain can increase mixing time and lower NOx
- May need to maintain some light n-paraffin for ignition
- Fuel hydro-treatment removal lower soot, reduce coking

Lean-burn Advantage at Cruise



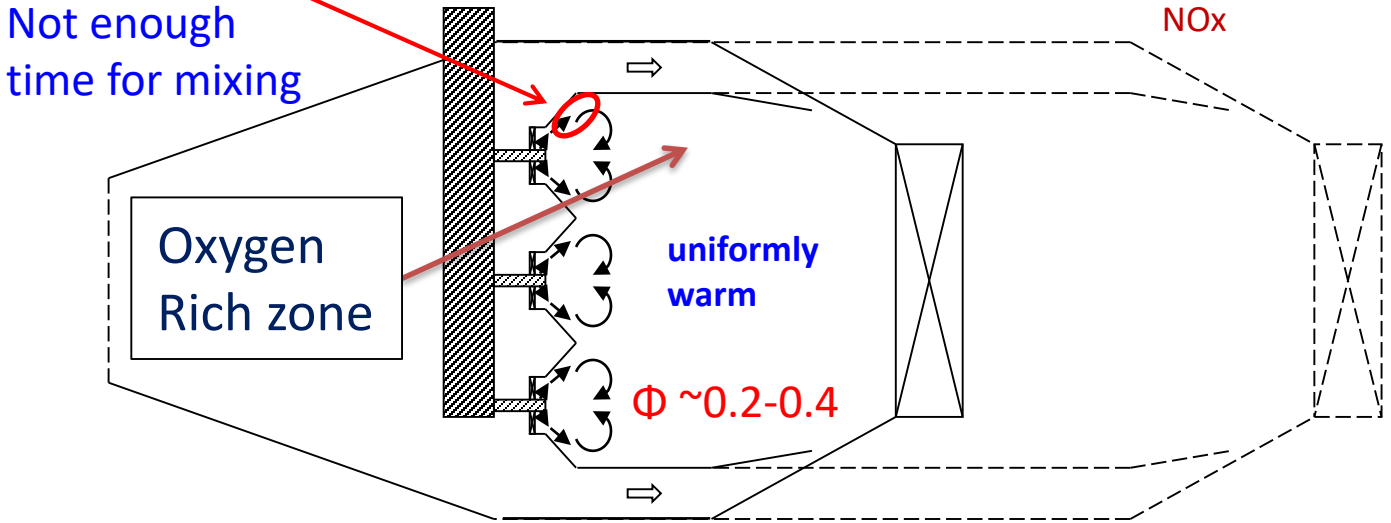
Lean-Burn: Avoid making CO & soot in the first place

Rich burn



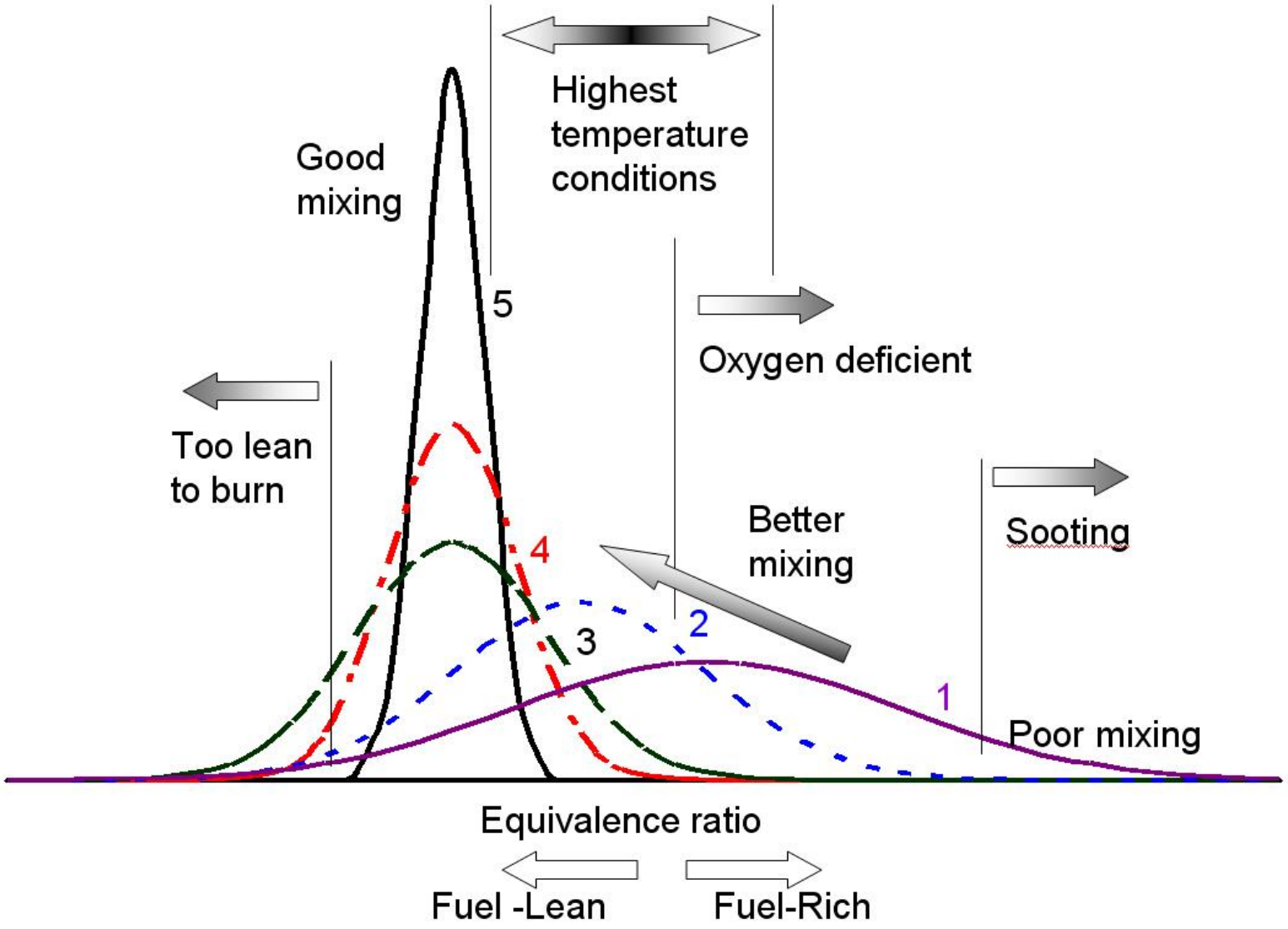
Less sensitive to fuel variation

Lean burn

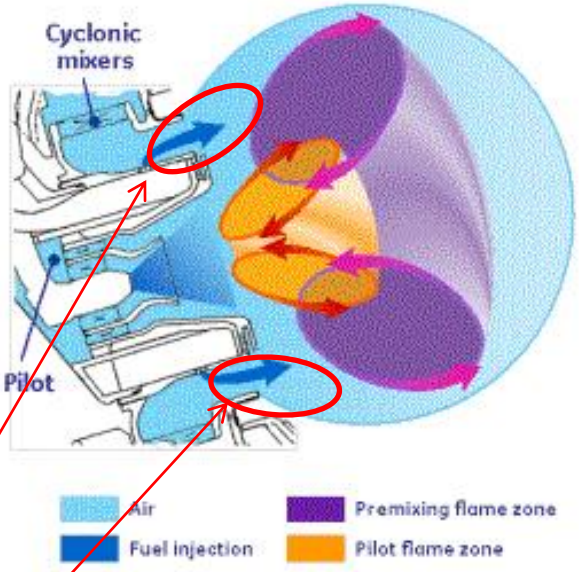


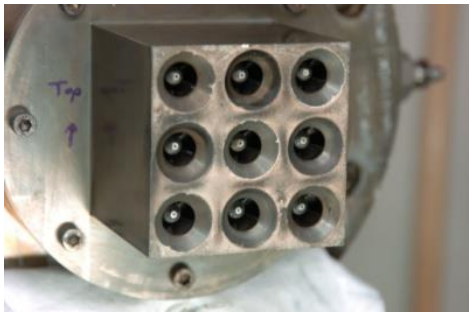
Possible Low-Power ignition and High-Power auto-ignition and coking issues

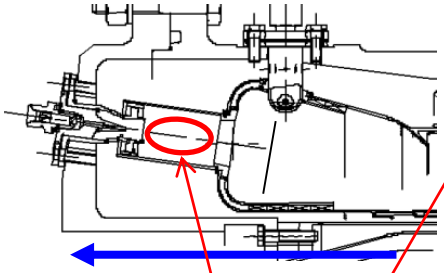
Quick Fuel-Air Mixing Critical to Clean Combustion



Maximum Combustor Pressure Dictates Viable Lean-burn Combustor Strategy







Lean Direct Injection

Lean Partial-Premixed

Lean Premixed Prevaporized

25 35 45 55 65 75

Max Combustor Pressure

Pre-mixing zones sensitive to auto-ignition

Higher inlet temperature, Shorter ignition delay time, Less mixing time, Higher NOx

Fuel Variation Concerns on Lean-Burn

- Coking: Limits minimum orifice size →
  - Limits atomization rate → Higher NOx
- Auto-ignition / Flashback:
  - Hardware damage
  - Unanticipated dynamics
- Lean blowout: Engine stability

Fuel Tweak Opportunity:

Fuel hydro-treatment (Injector coking reduction)

Aromatic reduction (Soot reduction)

(Lower liner heat load)

Sulfur removal (Contrail reduction)

Cetane number control

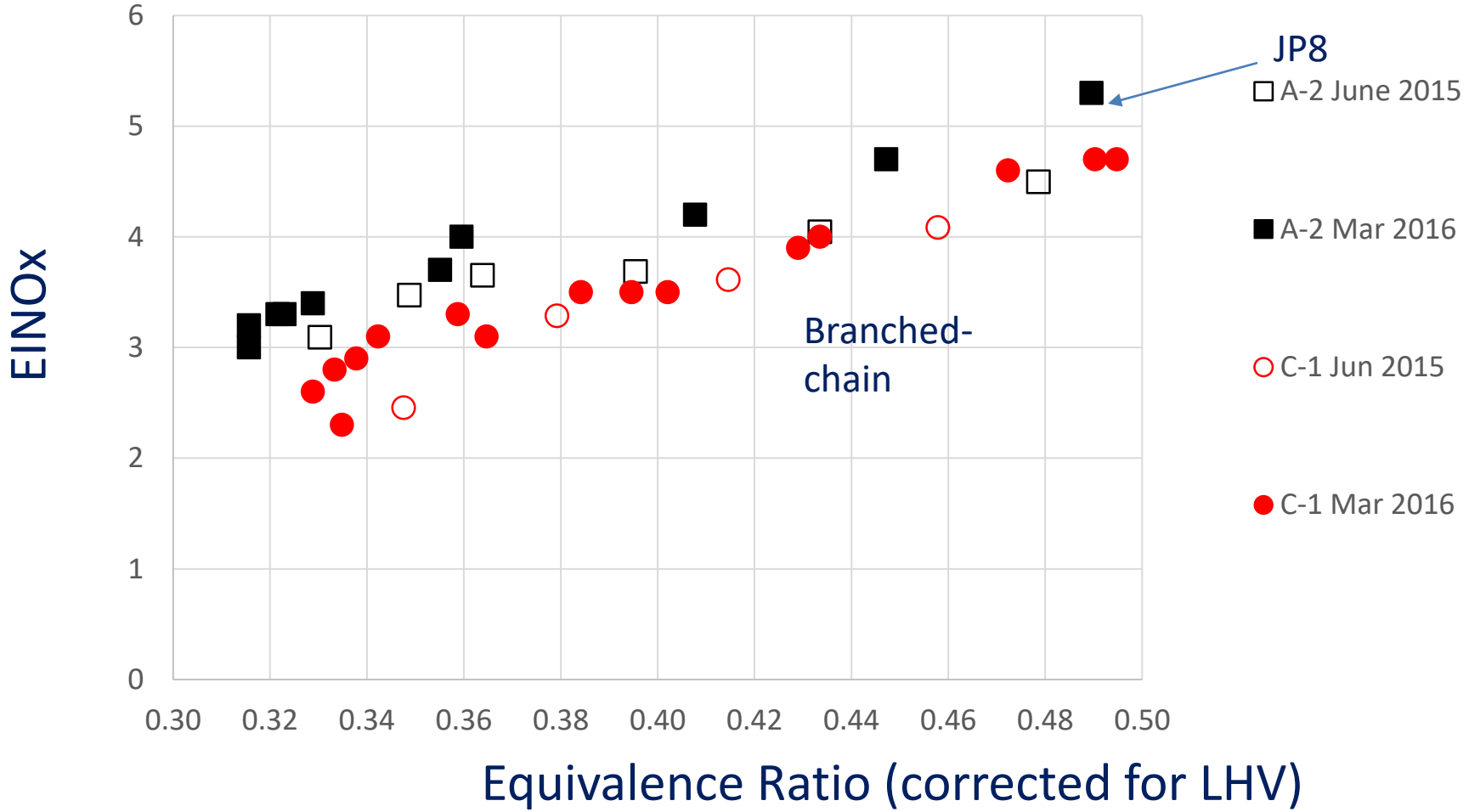
Limit n-paraffin content (Increase ignition delay)

Improve auto-ignition margin

Maintain some light n-paraffin for ignition

Cetane Number: Slower Branched-chain Pyrolysis

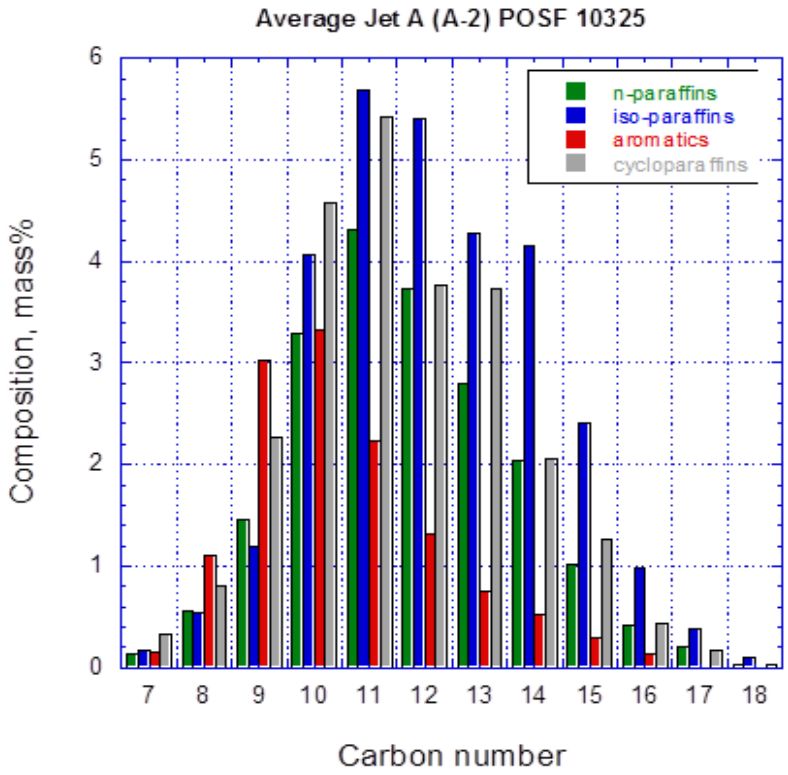
Give me a little more mixing time…

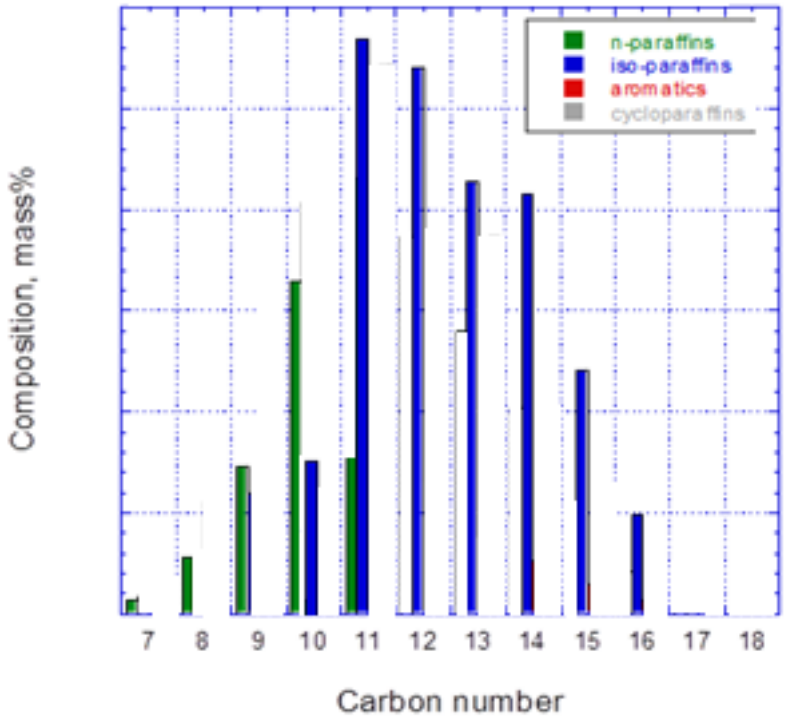


But… Lower-Power Operation…

- Do not atomize fuel well
  (slow fuel flow, low air density)
- Vaporize fuel slower
- Poorer fuel-air mixing
- More unburnable fuel-air packets
- Needs faster burning (n-paraffin) components
- Perhaps… Need light n-paraffin components to maintain ignition characteristic

Selective Carbon-number Distribution?





- Limit C<7 for fuel tank flammability
- Limit C> ~16 (or really heavy stuff) to avoid prolonged localized fuel-rich condition
- Need enough **light-end fraction** for low-power ignition (for fuel vaporization rate control)

Summary

- Lean-burn NOx and nvPM advantage at cruise
- Fuel injector performance critical to lower NOx
- High OPR lowers available mixing time
- Controlled fuel composition (cetane number) to bracket ignition characteristic
- Maintain enough light n-paraffin for low power ignition.
- Hydro-treatment to reduce coking