National Jet Fuels Combustion Program

Status Update

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ASCENT Fall MEETING
October 23, 2019
Alexandria, VA

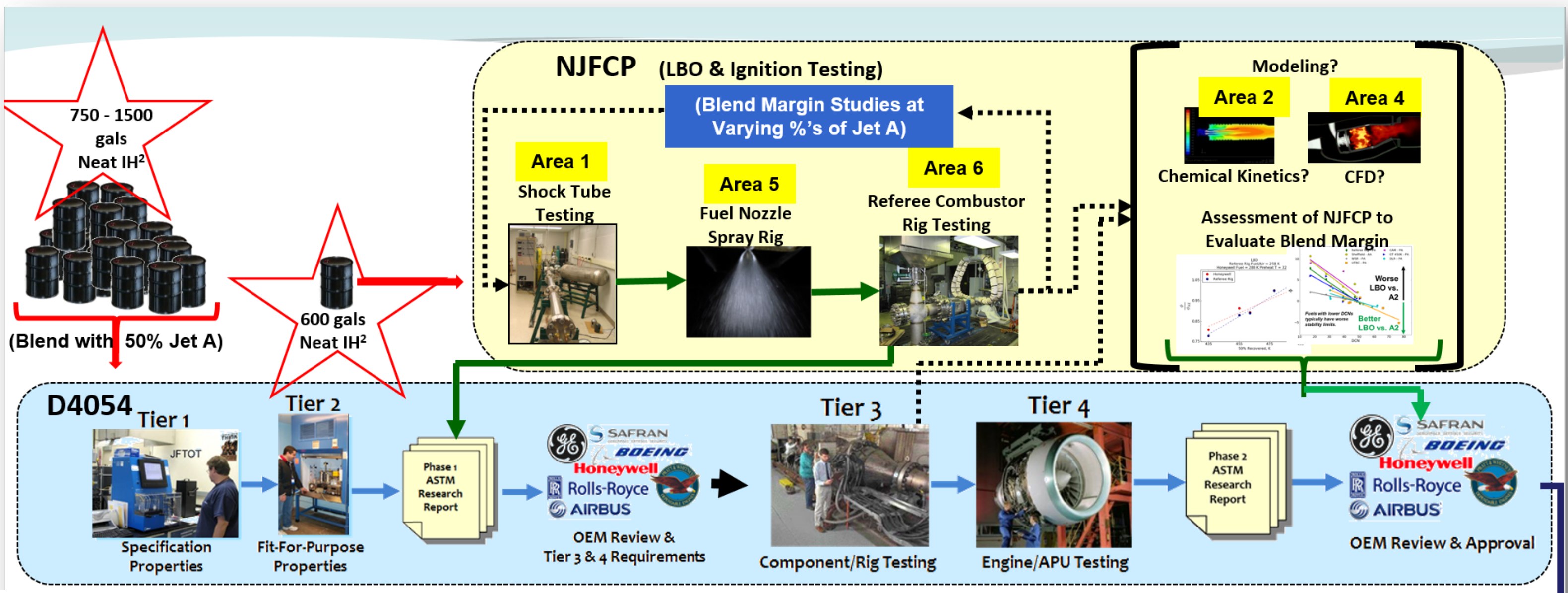
CPK-0 (IH²) NJFCP - D4054 Testing

Completed NJFCP Testing:

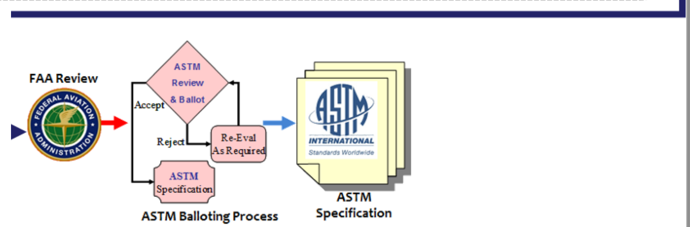
- ***Shock Tube IDT, IR measurements,***
- ***LBO (Referee Rig).***

Planned NJFCP Testing:

- ***Speciation (F19), IR spectra property predictions (F19),***
- ***Cold LBO (Referee Rig), Ignition (Referee Rig) (S19).***



CPK-0 composed primarily of cycloalkanes (0% aromatics) - significantly different composition compared to conventional jet fuel.



Mark Rumizen
July 26, 2018

Documentation and Dissemination Progress

- CPK-0 (IH²) NJFCP results submitted to ASTM and expected to be included in Phase I research report
  - Ignition Delay Time (IDT) and Warm LBO testing did NOT indicate any large differences relative to Cat-A fuels
- Prescreening Procedure and Guidance
  - CAAFI Prescreening Guidance Document (posted Sept. 19) outlines low fuel quantities to make early estimate of key fuel properties and effects on combustor operability,
  - CAAFI Webinar (17 Oct.)
  - More detailed manuscript in preparation with the European JETSCREEN community
- AIAA book on fuel effects in combustors is nearly complete
- Invited (and sponsored) presentations:
  - EU Commission (Nov.), DLR Germany (Nov.), and
  - KAUST (Feb.)

National Jet Fuels Combustion Program

Agencies, institutes, contributors, OEMs, and universities

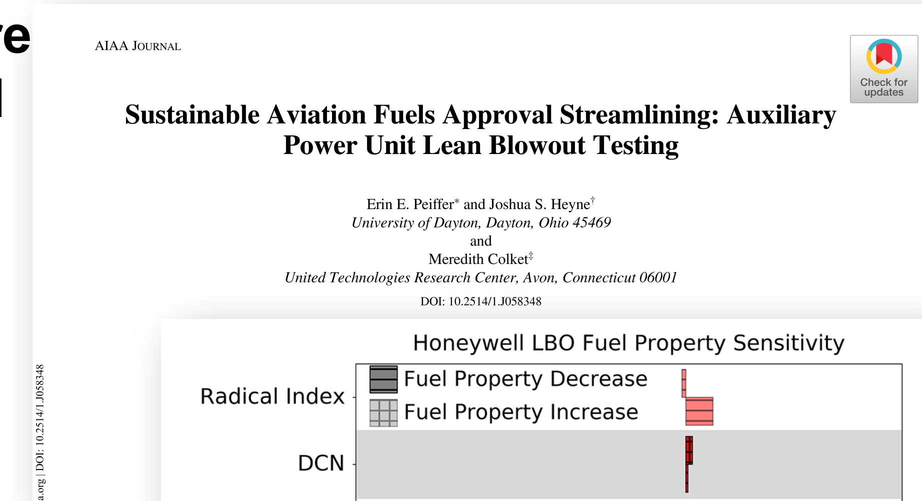
NIST
National Institute of Standards and Technology
U.S. Department of Commerce
Canada
NRC·CNRC
NAVAIR
Parker Aerospace
United Technologies Research Center
Rolls-Royce
ANSYS
Honeywell
Williams International
University of Cambridge
Convergent Science
ARL
ASCENT
Aviation Sustainability Center
Georgia Institute of Technology
Stanford
Purdue University
UCONN
Oregon State University
University of Dayton
Trinity College Dublin
The University of Dublin
University of South Carolina
Illinois
The University Of Sheffield.
USC University of Southern California
Federal Aviation Administration
NASA
Department of Energy United States of America
Air Force Office of Scientific Research
United States Air Force
Air Force Research Laboratory
Defense Logistics Agency
DLR
GE
Pratt & Whitney
Dependable Engines

NJFCP Major Take-aways

1. **Three Referee Rig operating conditions are sufficient to capture Figure of Merit variance across all rigs.**
   - *'Hot' LBO*
   - *'Cold' LBO*
   - *'Cold-altitude' Ignition*

2. **Referee Rig demonstrates fuel sensitivity for all three FOMs**
   - *Referee Rig fuel sensitivity is larger than other rigs for which we have test data*

3. **Approximately 8 properties are able to account for all observed variance.**
   - *These results are summarized in part with several publications.*



AIAA Journal

Sustainable Aviation Fuels Approval Streamlining: Auxiliary Power Unit Lean Blowout Testing

Erin E. Peiffer* and Joshua S. Heyne†
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Meredith Colket‡
United Technologies Research Center, Avon, Connecticut 06001

DOI: 10.2514/1.J058348

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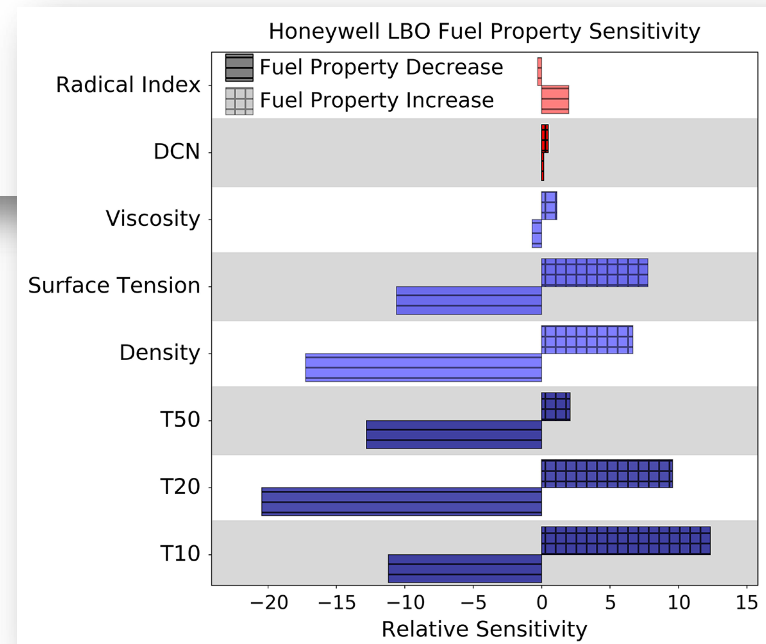

NJFCP Major Take-aways

1. Three Referee Rig operating conditions are sufficient to capture Figure of Merit variance across all rigs.
   - *'Hot' LBO*
   - *'Cold' LBO*
   - *'Cold-altitude' Ignition*

Tier 2.5 Testing (Referee Rig)

2. Referee Rig demonstrates fuel sensitivity for all three FOMs
   - *Referee Rig fuel sensitivity is larger than other rigs for which we have test data*

Prescreening with mLs of fuel

3. Approximately 6 properties are able to account for all observed variance.
   - *These results are summarized in part with several publications.*

AIAA JOURNAL

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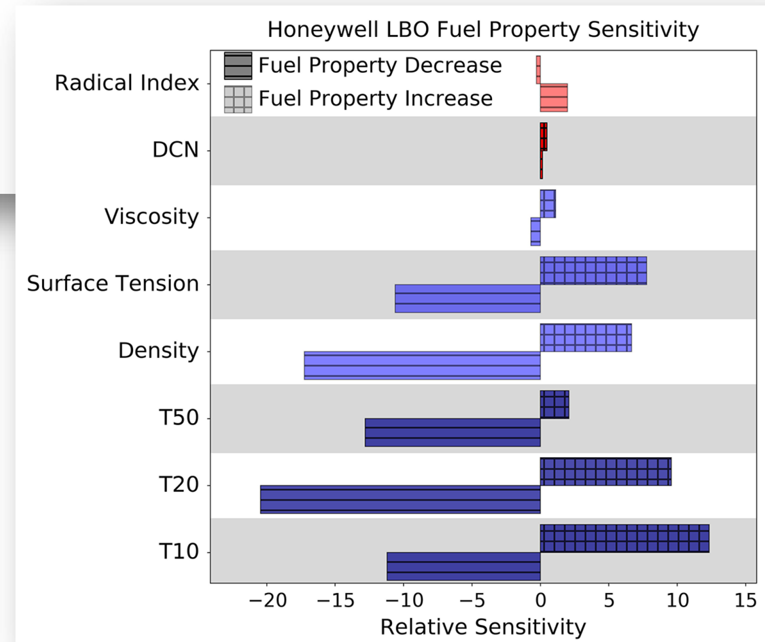


Tiered Screening/Approval: Predicting and Capturing All Variance

Prescreening

mLs

Tier α

Property Predictions & Blend Estimations

- GCxGC,
- IR absorption, and/or
- NMR

~1/4 gal

Tier β

Critical Properties & Blend Limits

- DCN
- Density
- Distillation Curve
- Viscosity
- Surface Tension

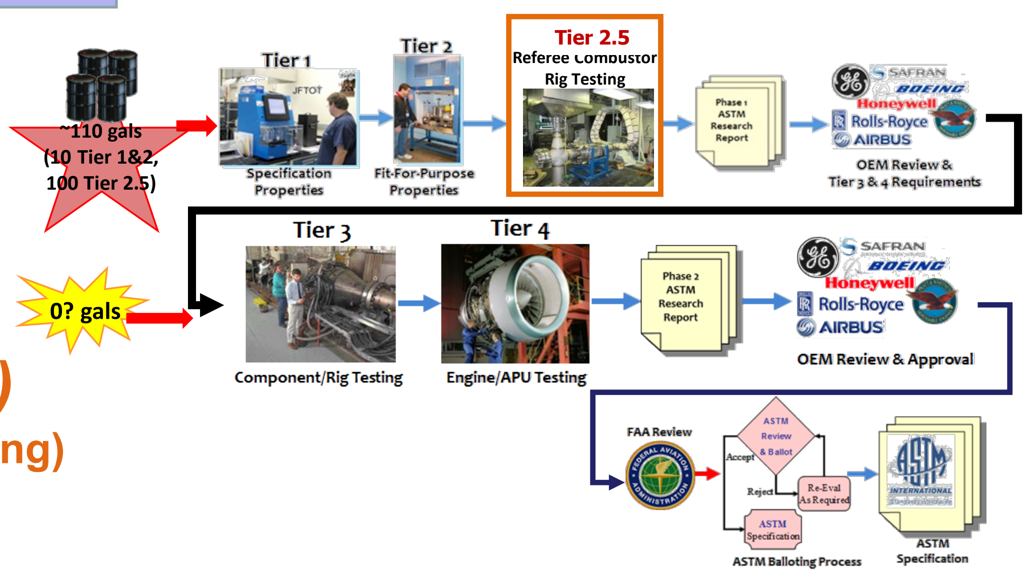
	Tier	$\mathcal{O}$(gal)
Prescreening	α	~10^{-4}
	β	~10^{-1}
	1 & 2	~10^{2}
Optional testing →	2.5	~10^{2}
	3 & 4	~10^{3}

D4054

***Proposed* ASTM D4054**

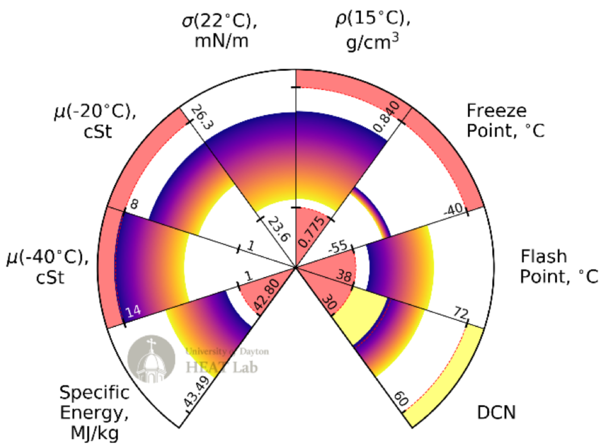
Optional testing (Tier 2.5)

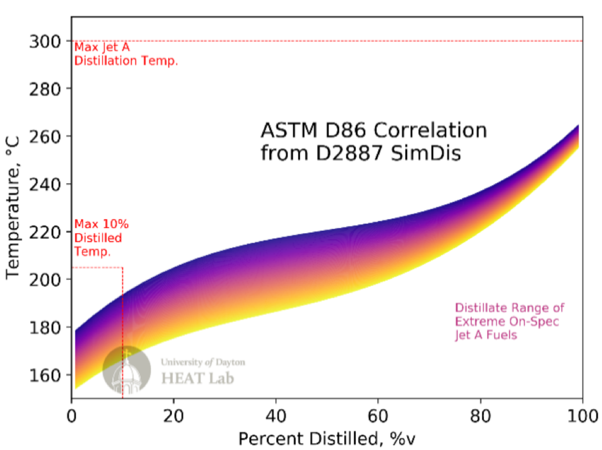
(to reduce or eliminate Tier 3 and 4 testing)



CAAFI Prescreening Document

Summary of NJFCP Results and Recommendations for Novel Producers
http://caafi.org/tools/Prescreening_Guidance.html





Evaluation metrics, tests, and volumes are proposed.

Version 1.0, Sep. 2019

CAAFI

Research & Development Team
Technical Guidance Document[a]

Prescreening of synthesized hydrocarbons intended for candidates as blending components for aviation turbine fuels (a.k.a. alternative jet fuels or AJF)[b]

INTRODUCTION

The aviation industry's evaluation and qualification process for synthesized jet fuel components, as detailed in ASTM D4054[c] and elsewhere,[1] can involve four tiers of testing, two research reports, and three balloting junctions. This process can be resource-intensive but ensures that any alternative fuel specification approved by the industry outlines the production of safe, fungible Alternative Jet Fuel (AJF) that is compliant with stakeholder demands arising from their insights into the need for such physical and fit-for-use properties. However, this process can span multiple years at significant cost to all parties involved, making mid-course fuel qualification corrections painful to prospective AJF developers. The extensiveness of this process has highlighted a need for early-stage, low volume, low cost, and rapid prescreening techniques outside the formal ASTM D4054 approval and evaluation process; especially those that relate to the assessment of jet engine combustor operability, which are among the most expensive testing requirements of the evaluation process. This document identifies prescreening methods that can provide early-stage confidence to fuel developers on whether AJF formulations might encounter downstream challenges with the completion of the ASTM D4054 evaluation process.

These prescreening methods have been developed from learning acquired from the National Jet Fuels Combustion Program (NJFCP),[2] JETSCREEN,[3] prior industry approvals of AJF, and other associated AJF programs. These methods do not replace the ASTM D4054 evaluation process and its requirements. However, results from this prescreening should provide an early assessment of whether serious combustion issues could be encountered in the formal approval process. This could help AJF developers make early decisions on AJF composition or production processes that could help facilitate later approval, either for Fast-Track or Standard approvals (see ASTM D4054 Standard Practice).

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[a] Prepared by members of the National Jet Fuel Combustion Program (NJFCP) and other CAAFI constituents to facilitate the early evaluation of new jet fuel component candidates in conjunction with a potential producers' engagement with the aviation community via CAAFI through their R&D Team. Special thanks to Dr. Joshua Heyne of the University of Dayton for his expertise and commitment to identify and formulate this pre-screening protocol enabling the early assessment of candidate AJF viability.
[b] After completion of the blending requirements of ASTM D7566, and meeting various sustainability criteria, these AJF may also be referred to as drop-in Sustainable Aviation Fuels (SAF), the aviation industry's current consensus naming convention.
[c] ASTM International publication, Standard Practice for Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives.

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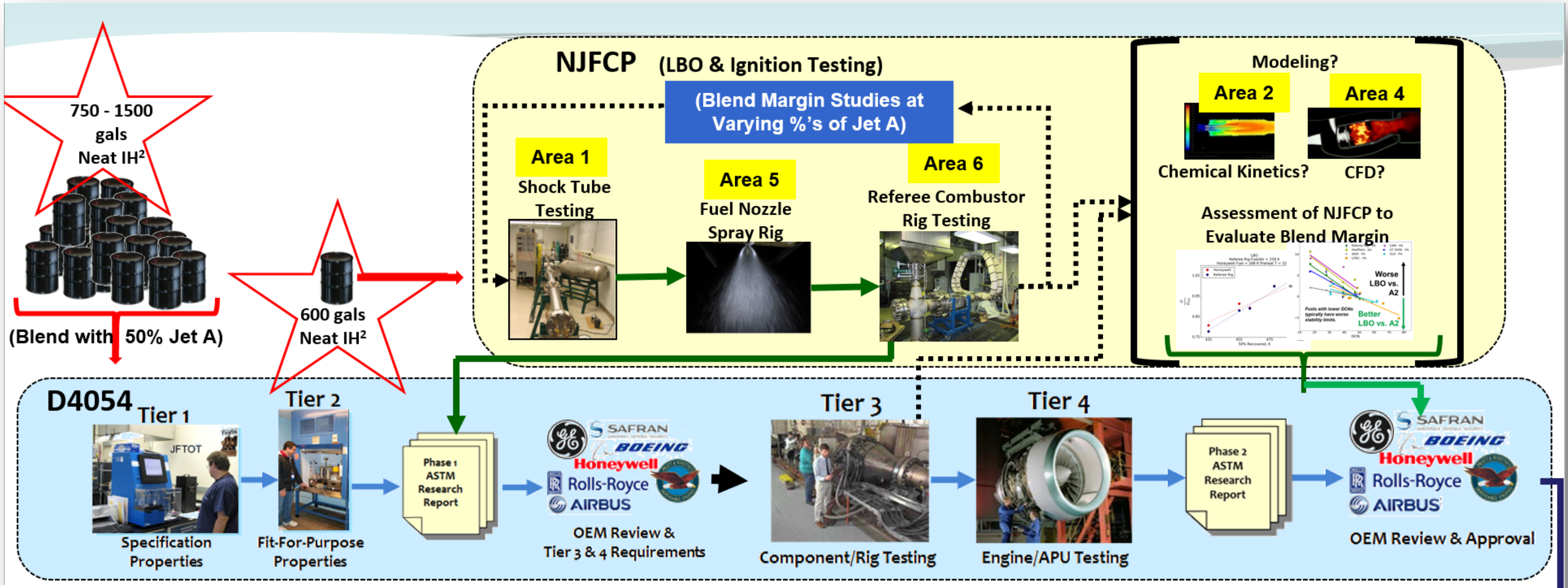
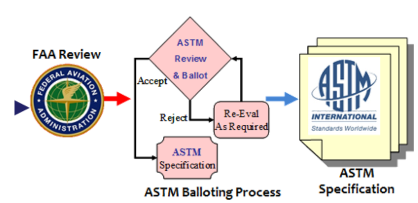
CPK-0 (IH^2) NJFCP-D4054 Testing

Significant NJFCP Testing Completed: Shock Tube, IR measurements, LBO.
Further NJFCP Testing Planned in 2020, including Cold LBO and Ignition.



CPK0 composed primarily of cycloalkanes (0% aromatics) - significantly different composition compared to conventional jet fuel.



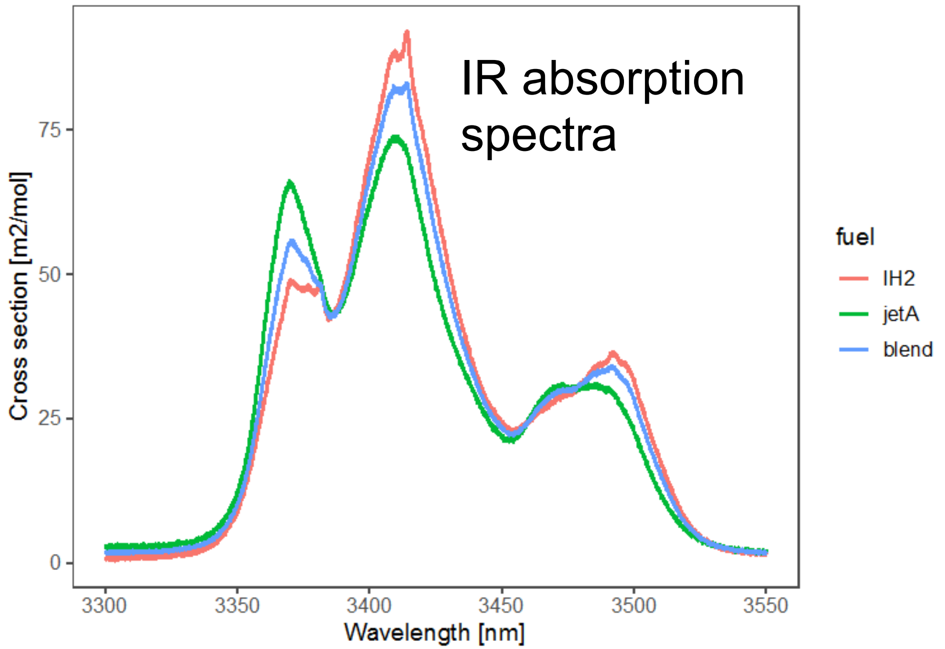
Mark Rumizen
July 26, 2018

CPK-0 (IH²) Testing

NJFCP testing is limited based on fuel volumes, funds available, and, to a lesser extent, timing.

- **Stanford and AFRL/UDRI submitted results on CPK-0 for inclusion in the Phase I research report.**
- **Additional data to be obtained later in 2019 and in 2020.**

Deriving CPK-0 (IH2) Fuel Properties Using IR Analysis

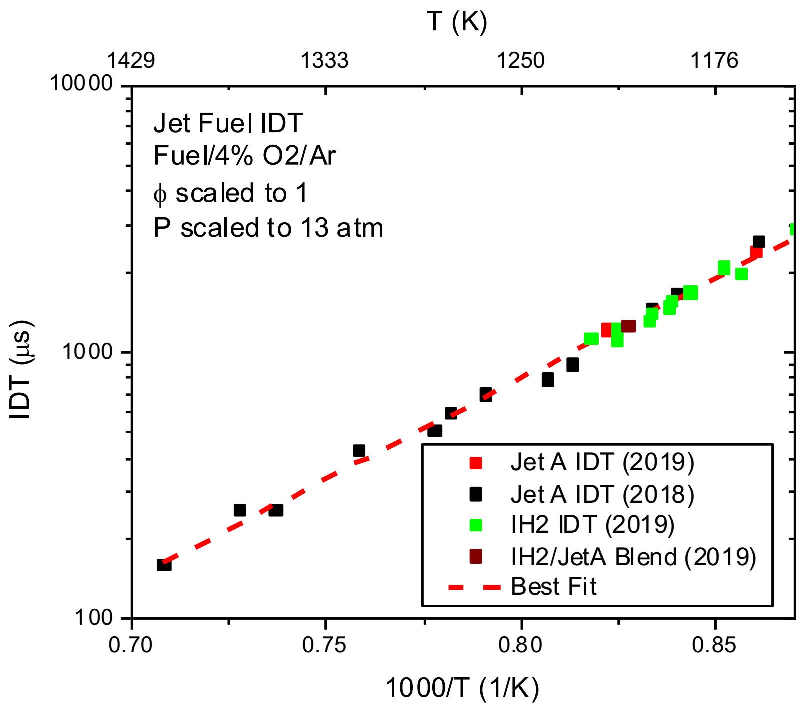


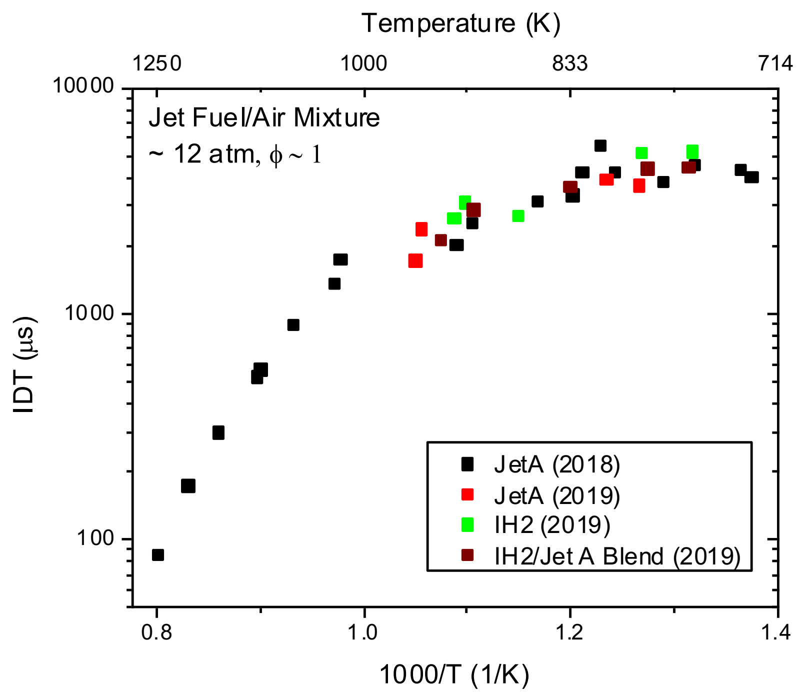
Jet A	Measured	IR Estimate	% Variation
DCN	49	46	-6%
Flash pt.	48	45	-6%
IBP	155	156	1%
Kinematic Vis.	4.6	4.7	2%
NHC	43	43	0%
Density	0.80	0.80	0%
Blend	**Measured**	**IR Estimate**	**% Variation**
DCN	44	46	5%
Flash pt.	42	52	24%
IBP	150	166	11%
Kinematic Vis.	4.4	4.6	5%
NHC	43	43	0%
Density	0.82	0.84	2%

- **Fuel properties, chemical and physical can be determined from IR absorption spectra**
- **Absorption spectra for CPK-0 (IH2), Jet A and blends were acquired, and fuel properties were determined using the IR spectra and compared with published values**
- **Preliminary Analysis shows good agreement on predicted fuel properties seen with Jet A and 50/50 blend**

Summary of Ignition Delay Time Data for Jet A & IH2

High T | **Low T**





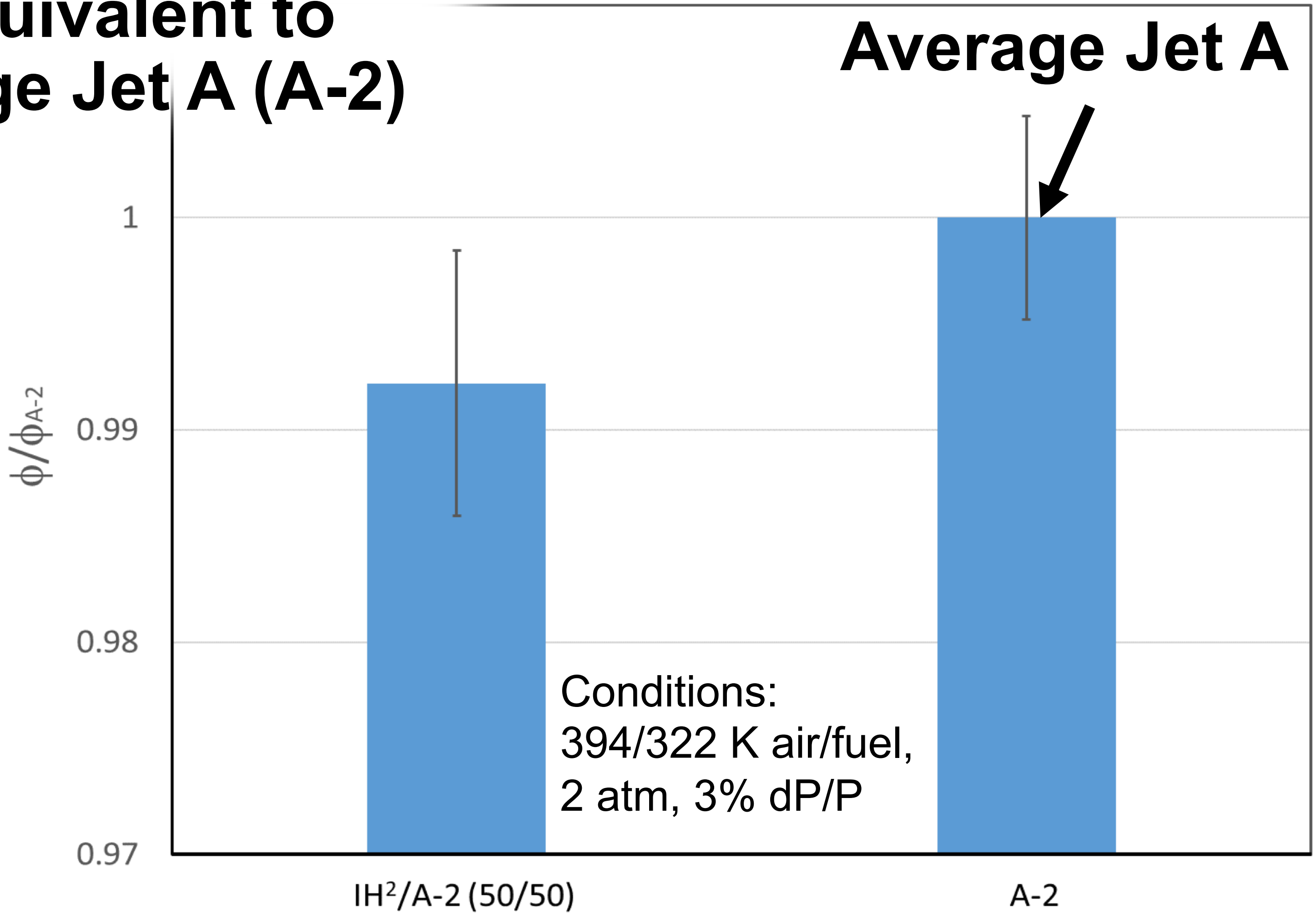
- Similar IDT seen for Jet A, IH2 and blend at high T

- Weak difference seen in IDT at Low (NTC) temperatures

Next: Differences in IDT pressure traces at Low T

CPK-0 vs. An Average Jet A (A-2): Referee Rig LBO Testing

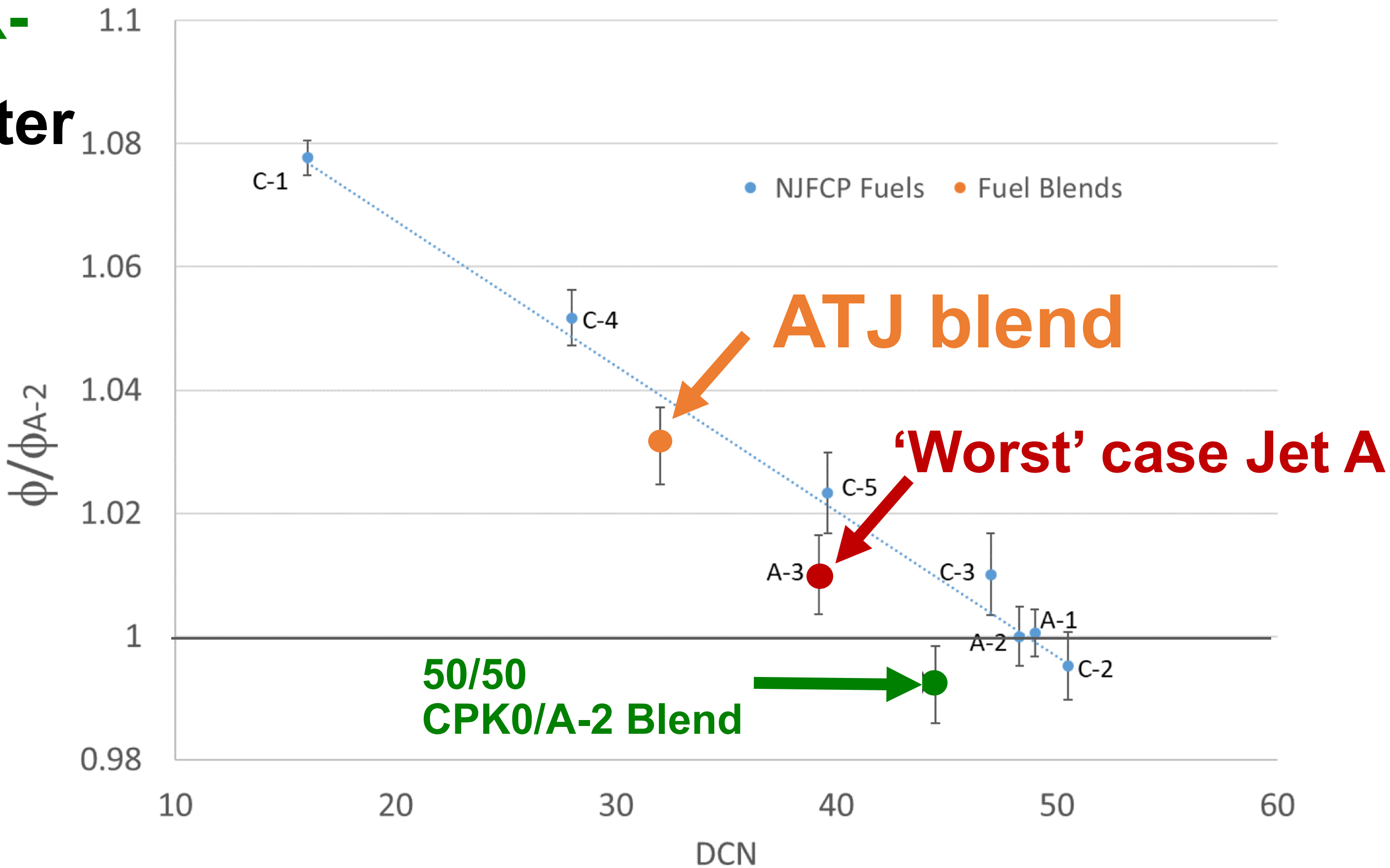
Performance of CPK-0 is nearly equivalent to an average Jet A (A-2)



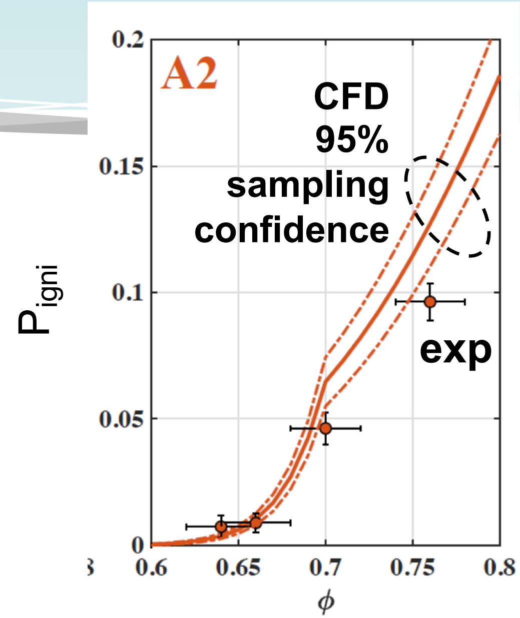
CPK0 Performs Better Than the Worst Approved Fuel in Hot LBO tests

The **50/50 CPK-0/A2 blend** performed better than:

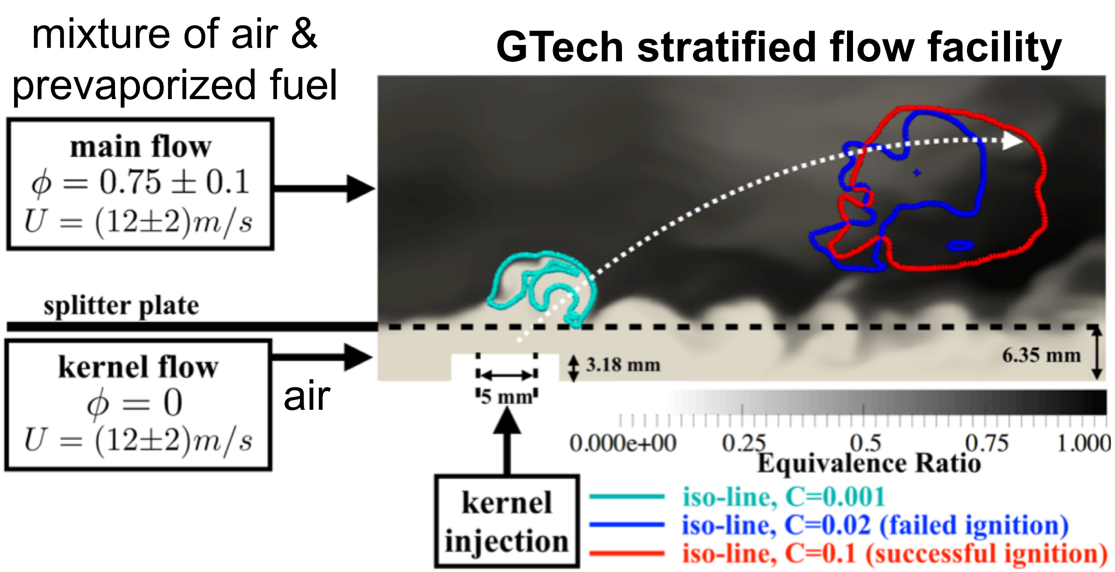
- **ATJ blend**
- **'Worst' case Jet A fuel**

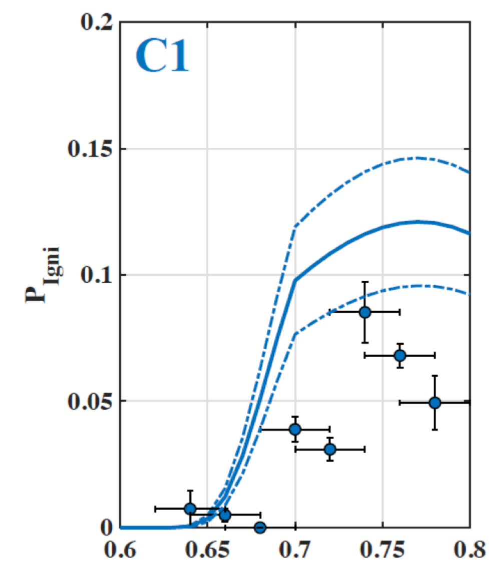


Ignition Fuel Sensitivity CFD Demonstrated



- Multiple simulations for each fuel (A2, C1, C5) varying ignition kernel energy and inflow turbulence (time-varying inflow BC)
- Three equivalence ratios (ϕ) simulated for each fuel
- Correct trend in ϕ and fuel dependence predicted for ignition probability (P_{igni})





AIAA-2019-2242, Y. Tang, et al.

Overall NJFCP Accomplishments Fall 2019

Previously Completed, Recently Completed, and Expected

- Demonstration of IR-property correlations, including LBO
- Refine pre-screening and screening process
- Definition of HyChem model for C-4 fuel
- Demonstration of screening method for CPK-0 (IH^2) Fuel
- CAAFI Prescreening document
- Explain variations in CFD modeling predictions for LBO limits
- Complete draft of book
- Full documentation of prescreening of new fuels and Tier 2.5
- Perform addition CPK-0 (IH^2) testing