CAAFI Prescreening

Motivation, process, and an example

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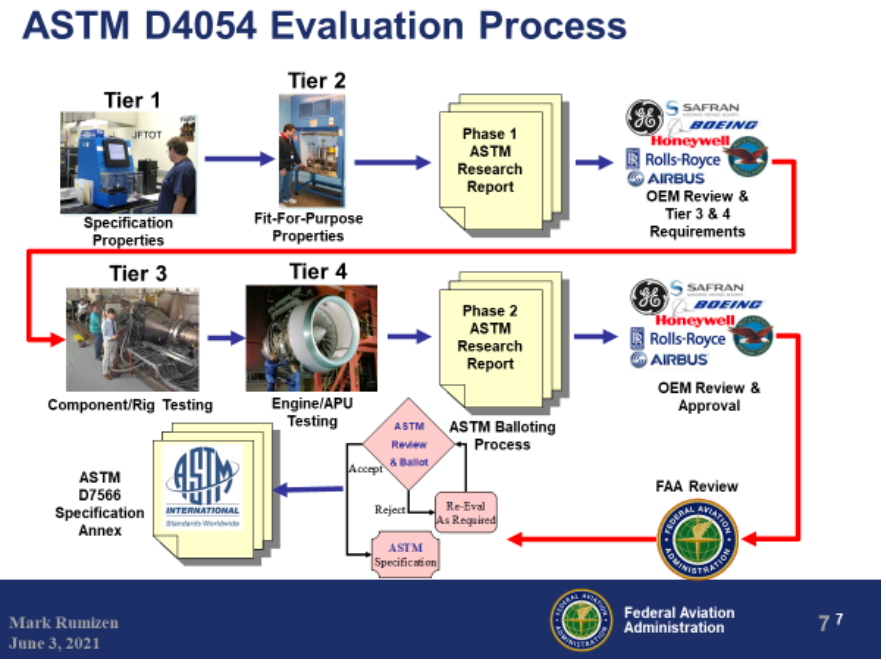
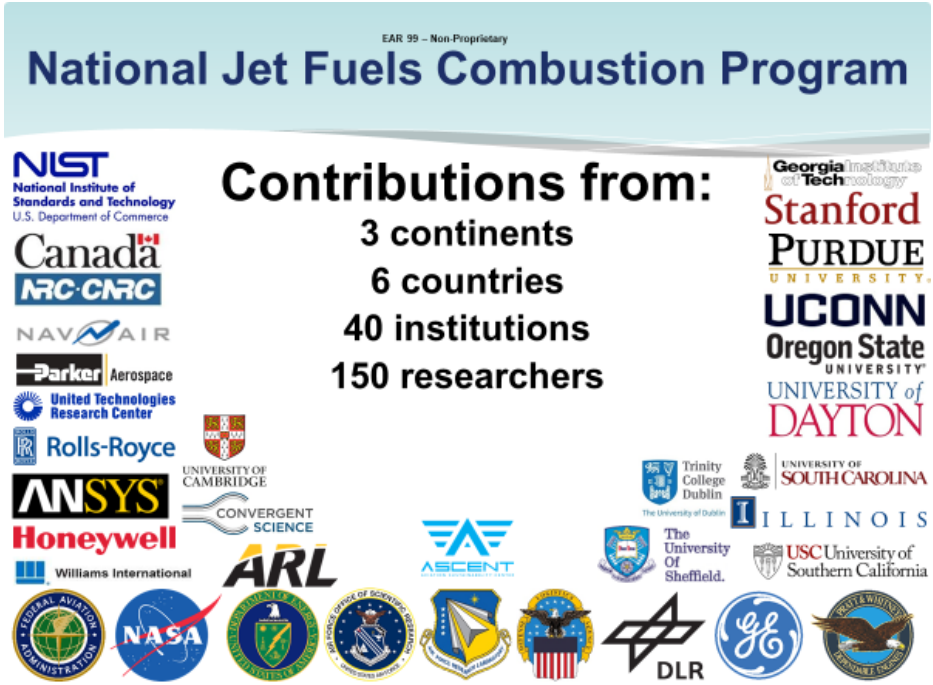
Alt. fuel evaluation and qualification route:

The motivation for the National Jet Fuels Combustion Program (NJFCP)



- Each Tier increases volume required and testing costs
  - Previous evolutions require 5 years and tens of thousands of gallons
- NJFCP's mission: *'streamline the evaluation process for alt. fuels'*
- Focused on Engine Operability
  - Lean blowout
  - Cold ignition
  - Altitude relight
- Maximize variance in
  1. **fuels,**
  2. **conditions, and**
  3. **geometry**

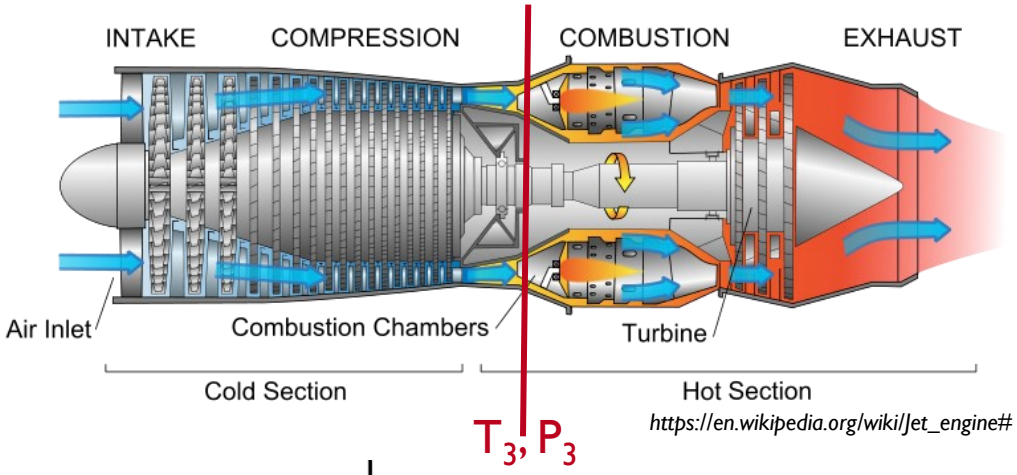


NJFCP Accomplishments

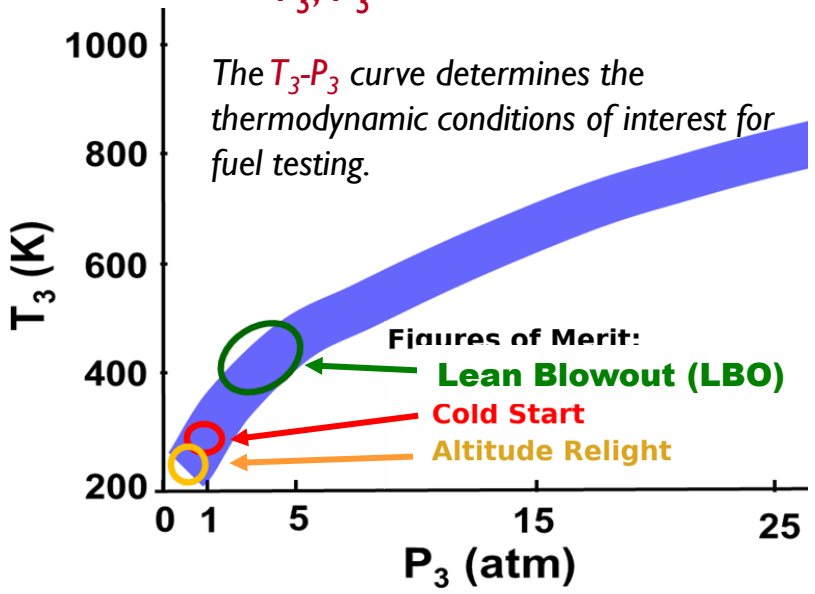
A novel combustor stabilization mechanisms was discovered

- Evaluation of ~12 fuels across dozens of experimental devices
- Analysis suggests bounding of **~8 properties** can account for **~90% of all observed variance**
  - Remaining variance is attributed to coupling of mass transfer and autoignition propensity
  - One unexplained observation remains.
- Referee Rig operability limits at relevant conditions match all known OEM hardware trends
- CFD matches operability trends for several fuels and conditions
- Process for custom chemical kinetics developed

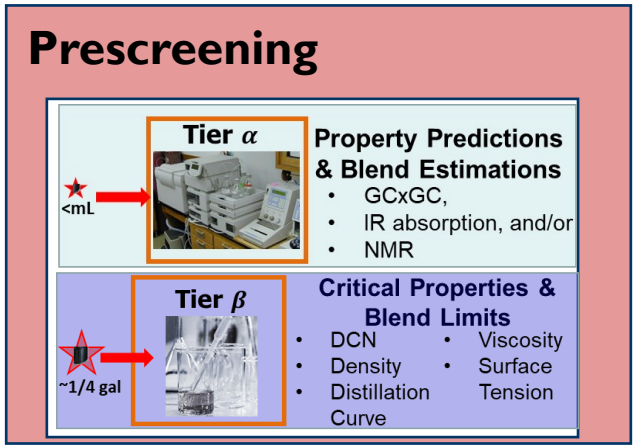
Gas Turbine Engine Schematic



https://en.wikipedia.org/wiki/Jet_engine#



NJFCP Outcomes and Learnings



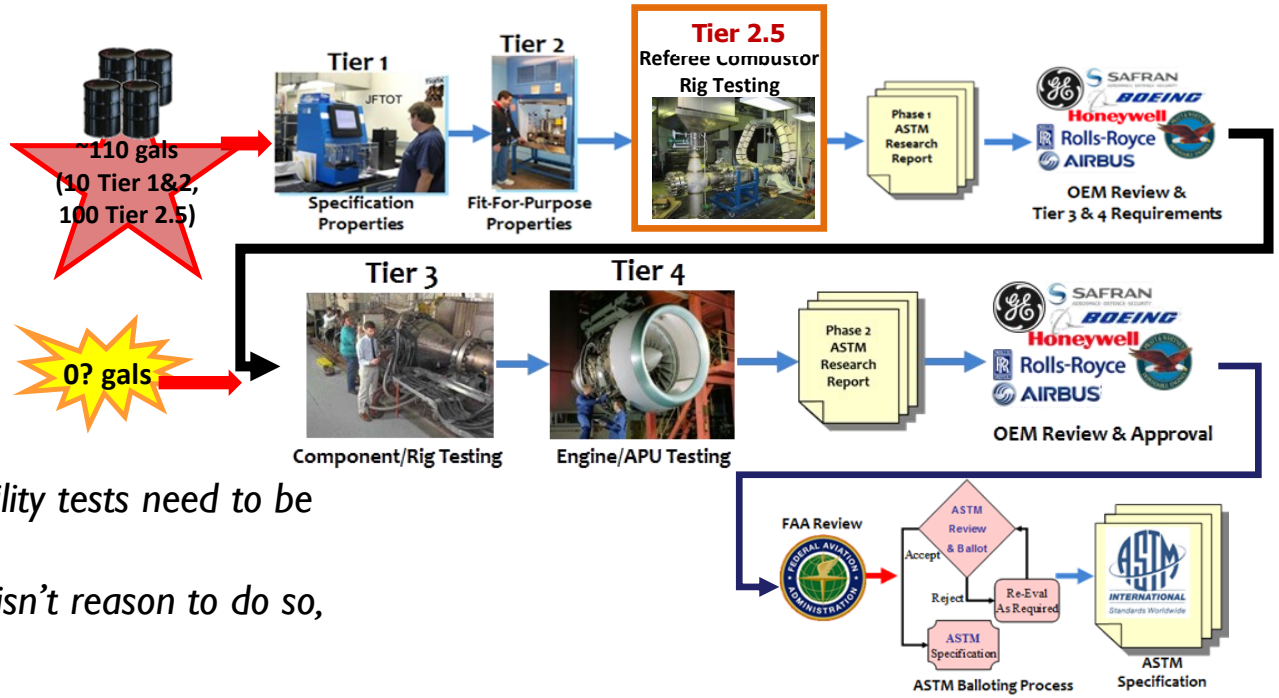
Tier	Measured Property	Predicted Property	Vol. (mL)	No. tested
α	GCxGC	LHV, Density, Surface tension, Freeze point, Viscosity, DCN, Flash point	1	61
	Distillation			
β	Density	LHV	10	38
	Viscosity			
	Surface ten.			
	Freeze point			
	Flash point			
	DCN		140	8

Guide compositions to meet properties most likely to eclipse Tier 3 and 4 operability tests with minimal volume requirements

Volumes needed for various testing Tiers

Tier	$\mathcal{O}$(gal)	
α	~10^{-6}	← Prescreening
β	~10^{-1}	← Prescreening
1 & 2	~10^{2}	
2.5	~10^{2}	← Referee Rig
3 & 4	~10^{3}	

Proposed ASTM D4054

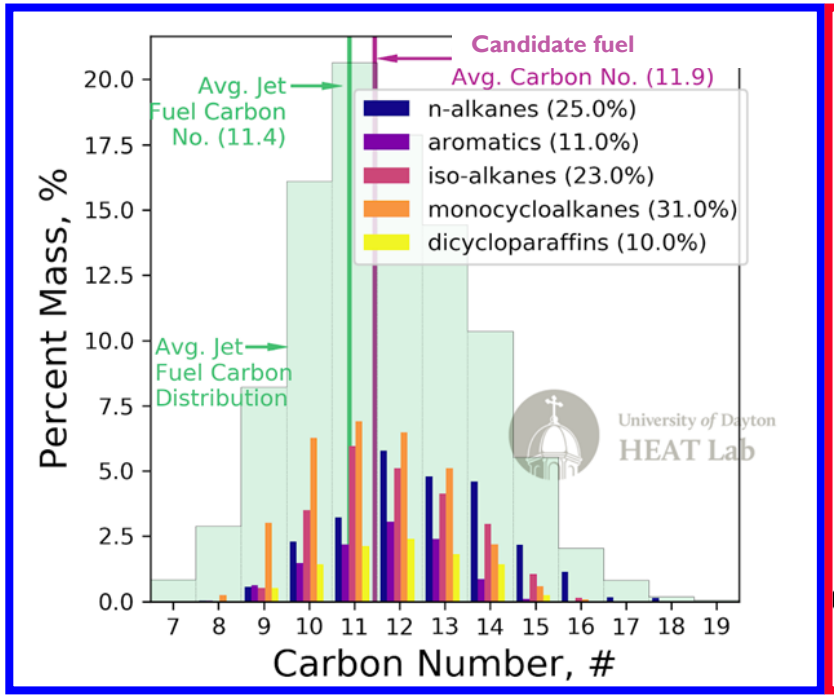


- *Elimination and/or minimization of operability tests (Tier 3 and 4)*
- *There is no evidence that operability tests need to be done at OEM facilities.*
  - *That does not mean there isn't reason to do so, however.*

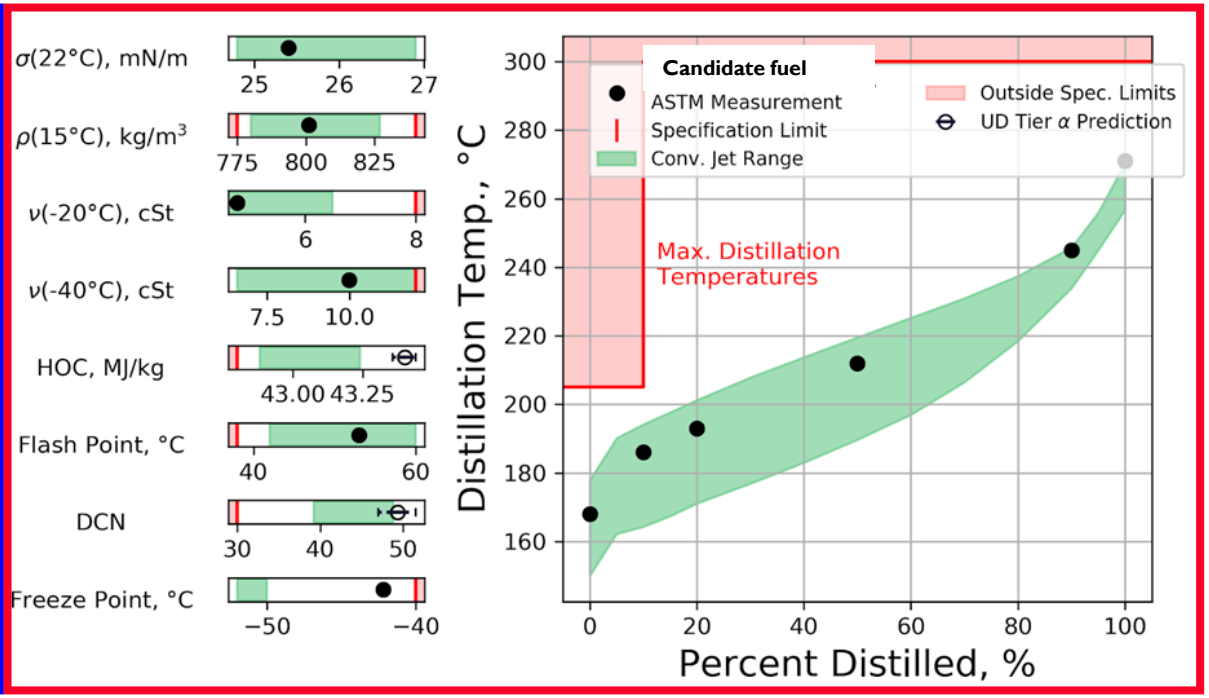
Prescreening example

Tier α and β prescreening dash-board

Compositional Comparison

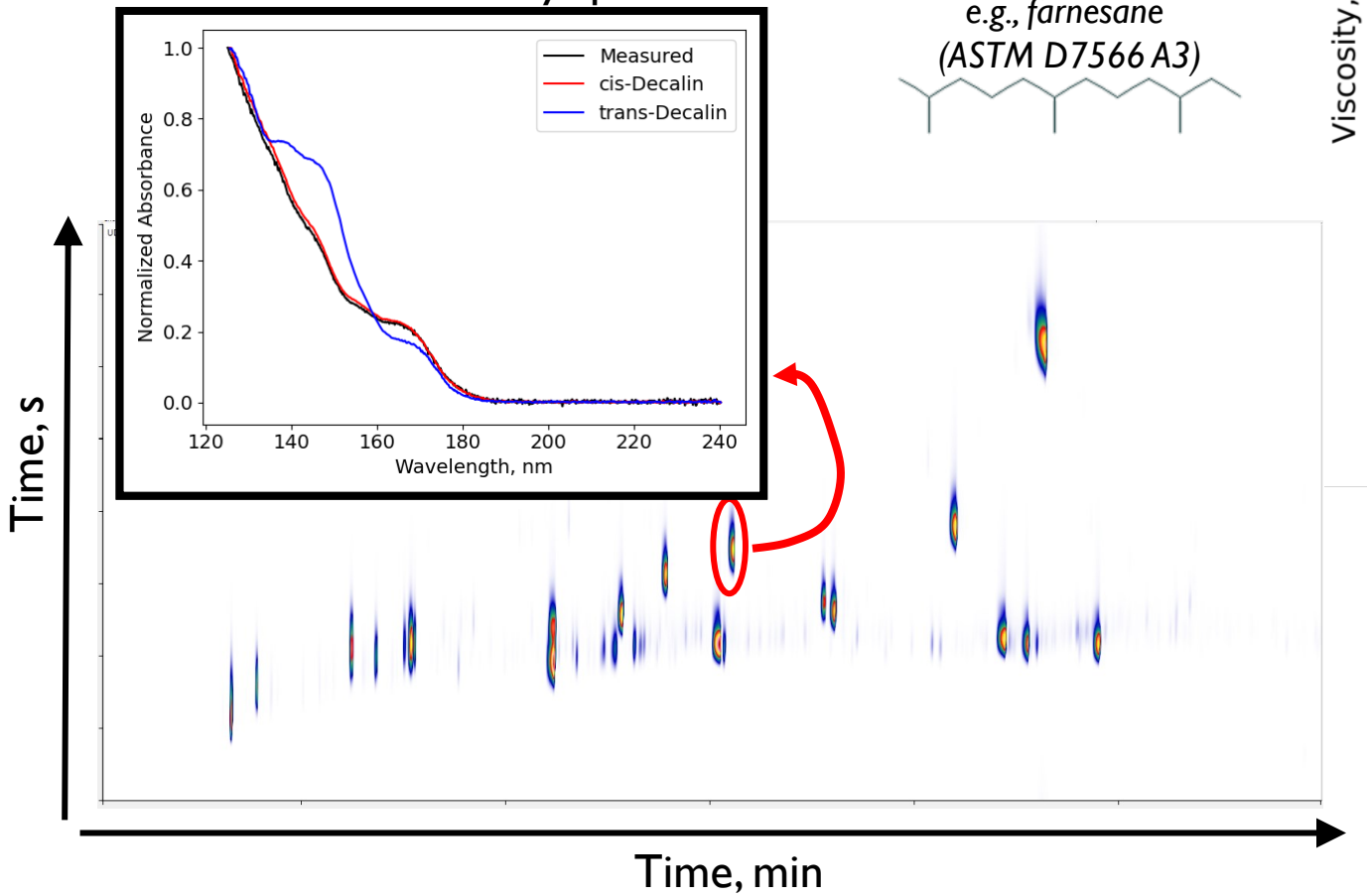


Operability Comparison

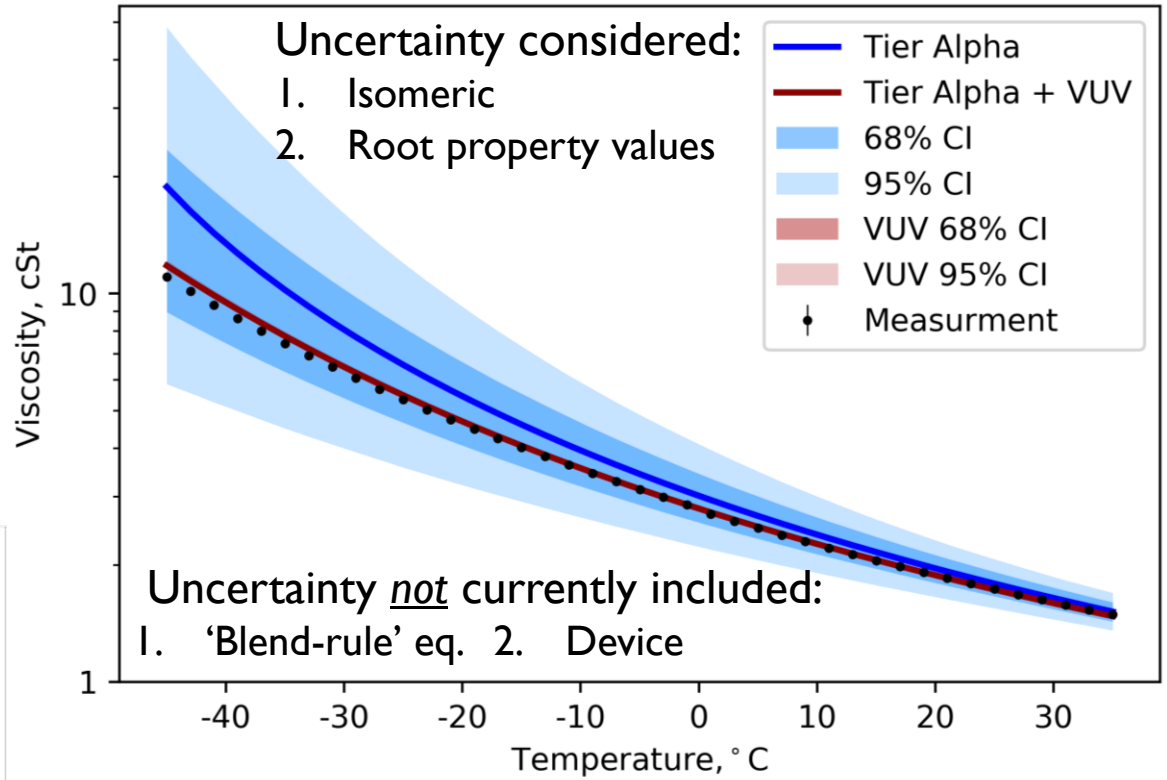


VUV identification with GCxGC separation

- ~2/3 of samples arrive in with <3 mL
  - *Critical properties are predicted*
- SAFs can have 'strange' and very specific isomeric structures
  - Isomeric uncertainty quantification is critical



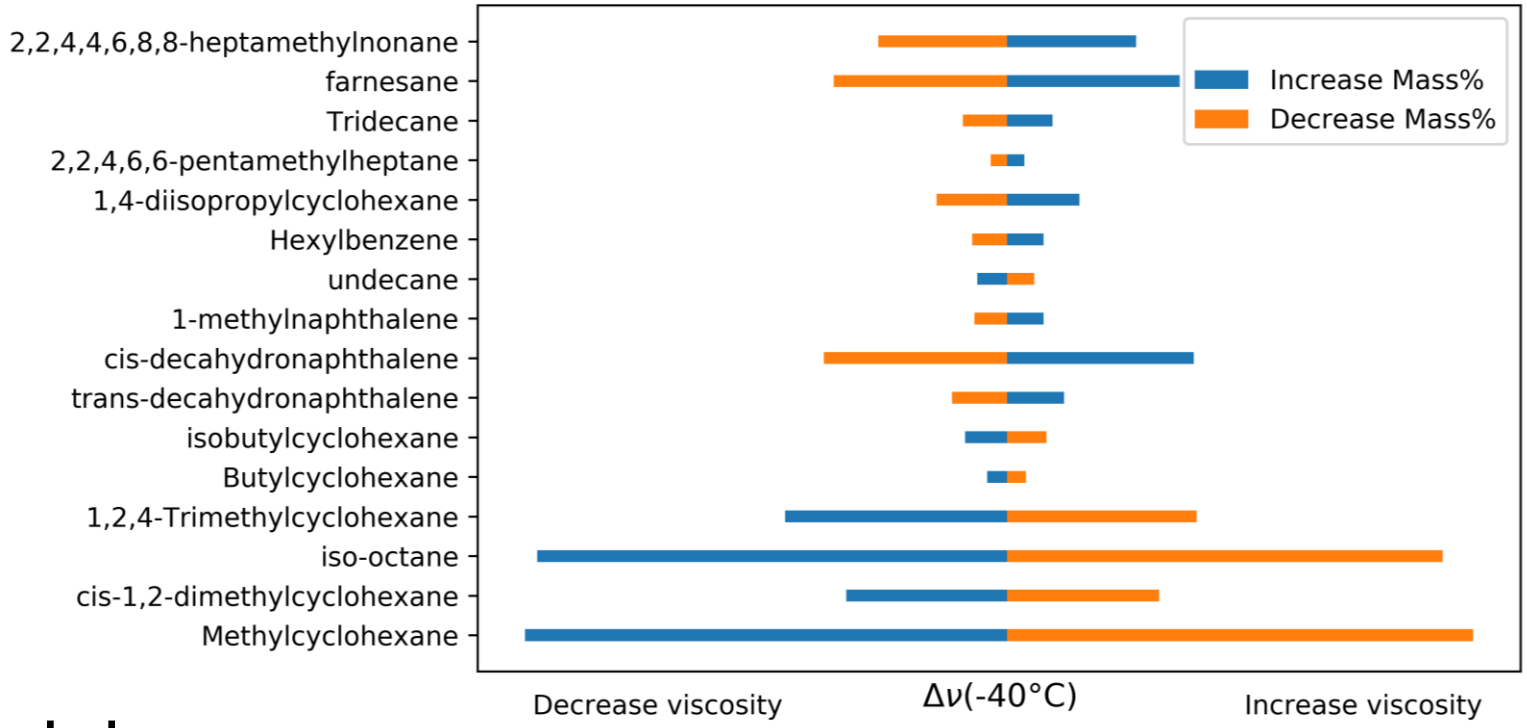
e.g., farnesane (ASTM D7566 A3)

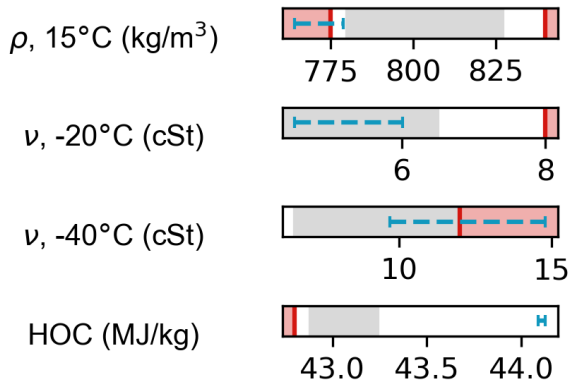


- 3-5k molecules and their associate properties are leveraged for predictions
- Blind Tier α predictions are compared with the VUV identification

Sensitivity analysis by property and specific analyte (or group)

- Some distillation cuts or process can have several properties off.
- Sensitivity analysis can illuminate which analyte(s) or hydrocarbon type(s) can facilitate compliance.
- Both property predictions and the associated sensitivity analysis can be done in the absence of sample but with some composition information





Conclusions

- ~8 different labs and companies have sent samples
- Some labs have changed/iterated methods significantly
- Technology development is useful at 1-3 mL
  - Expansion to additional simultaneous diagnostics would clarify and
  - Physical property measurements at very low volumes
- Three learnings a year+ in:
  - Distillation maters!
    - 160-240°C works well but could be dilated depending on feedstock-process
    - Depending on the hydrocarbon types, lighter or heavier cuts could be more compatible.
  - Trace materials are important (N and O)
  - Single component fuels will undergo more scrutiny.
- SAFs per expectation can be very strange

Thank you!

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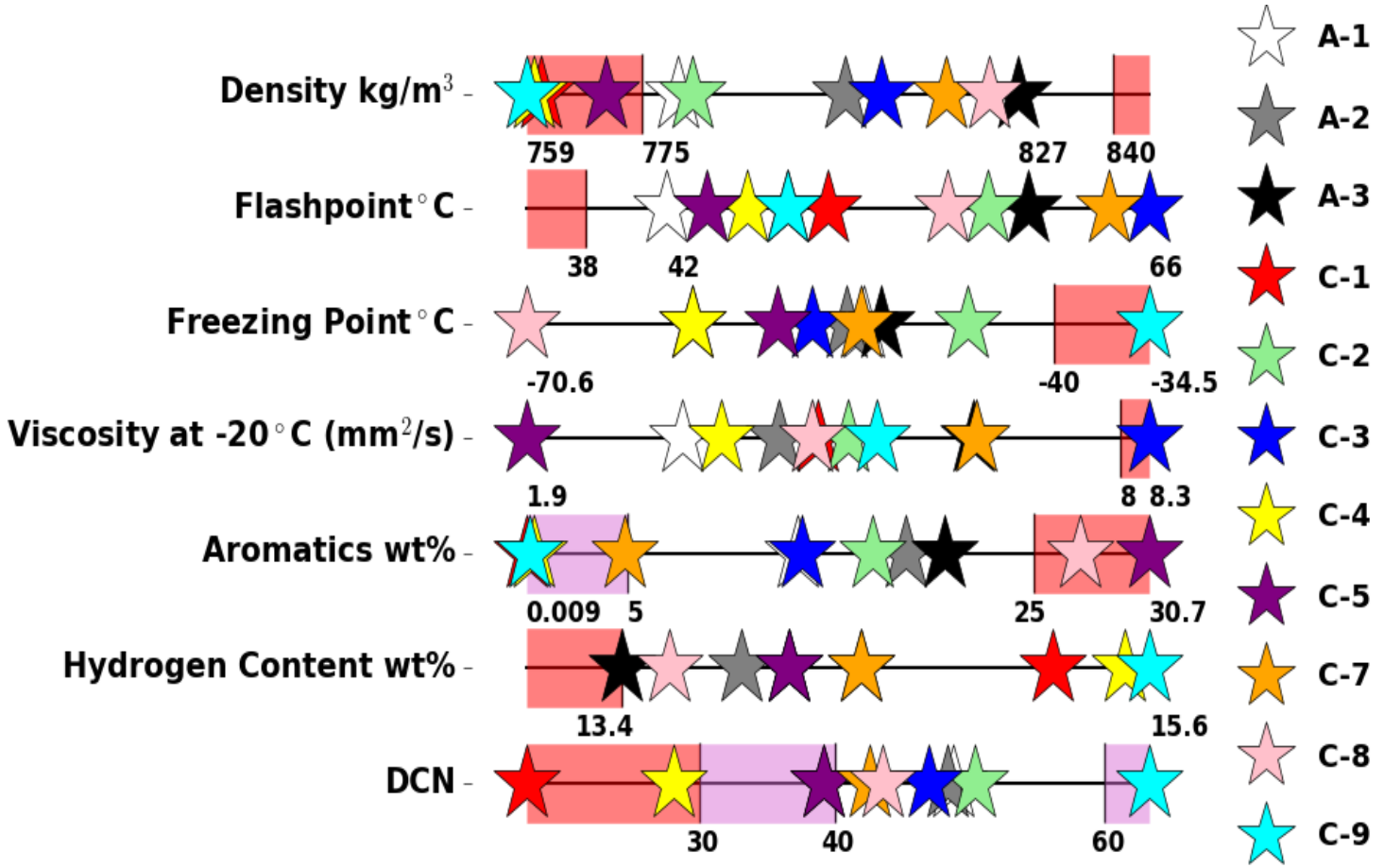
NJFCP Fuels

Category A: conventional fuels

- A-1: 'Best' case
- A-2: 'Average' case
- A-3: Worse' case

Category C: fuels that characterize alternative fuels with extreme properties



Edwards, T., "Reference Jet Fuels for Combustion Testing," *55th AIAA Aerospace Sciences Meeting*, Grapevine: American Institute of Aeronautics and Astronautics, (AIAA 2017-0146)