Alternative Jet Fuel Test and Evaluation Project 31

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ASCENT

University of Dayton

University of Dayton Research Institute

Project 31

Alternative Jet Fuel Test & Evaluation

University of Dayton Research Institute

PI: Zachary West

PM: Bahman Habibzadeh

Cost Share Partner(s): Global Bioenergies, Boeing, Shell, IHI, Neste, GE Aviation, NRC Canada, LanzaTech, REVO, and University of Dayton

Objective:

- **Coordinate and conduct performance testing** to support the **evaluation of novel alternative jet fuels** for ASTM approval and commercial adoption
- Develop the **analytical tools** necessary for commercial application of SATF

Project Benefits:

- ASTM research reports for OEM approval and **adoption of D7566 annexes**
- Management of **D4054 qualification process** of new fuel pathways
- Coordination of **fuel qualification to enable increased supply of secure and safe** synthetic blending components (SBC) and synthetic aviation turbine fuels (SATF)

Research Approach:

- Provide fuel property and composition testing & evaluation
- Facilitate the D4054 OEM review panel/approval process
- Act as liaison between new producers and OEMs
- Collaborate with UK & EU Clearing Houses
- Goals:
  - New or modified ASTM D7566 approved annex for prospective synthetic blend components (SBC)
  - Modification of ASTM D1655 to allow co-processing of alternative materials
  - Improve the D4054 process to enable faster, safer, and more reliable routes to synthetic aviation turbine fuels (SATF)

Major Accomplishments (to date):

- Approved 4 new and 1 major modification to ASTM D7566 Annexes (ATJ-SPK, CHJ, HC-HEFA, ATJ-SKA, ISB-SPK)
- Developed D4054 Fast Track Process
- Developed advanced chemical analysis methods: FCM-101, FCM-102, FCM-107
- Testing of CSIR-IIP, Revo, Marathon SAK, OMV ReOil, Methanol-to-Jet, UPM, and CleanJoule
- Guided Co-processing pathways in ASTM D1655

Future Work / Schedule:

- Continue guiding fuel producers through D4054 process
- Continue fuel testing & evaluation
- Continue OEM panel and report reviews toward ASTM approvals
- Advance test method capabilities for SBC/SATF adoption/evaluation

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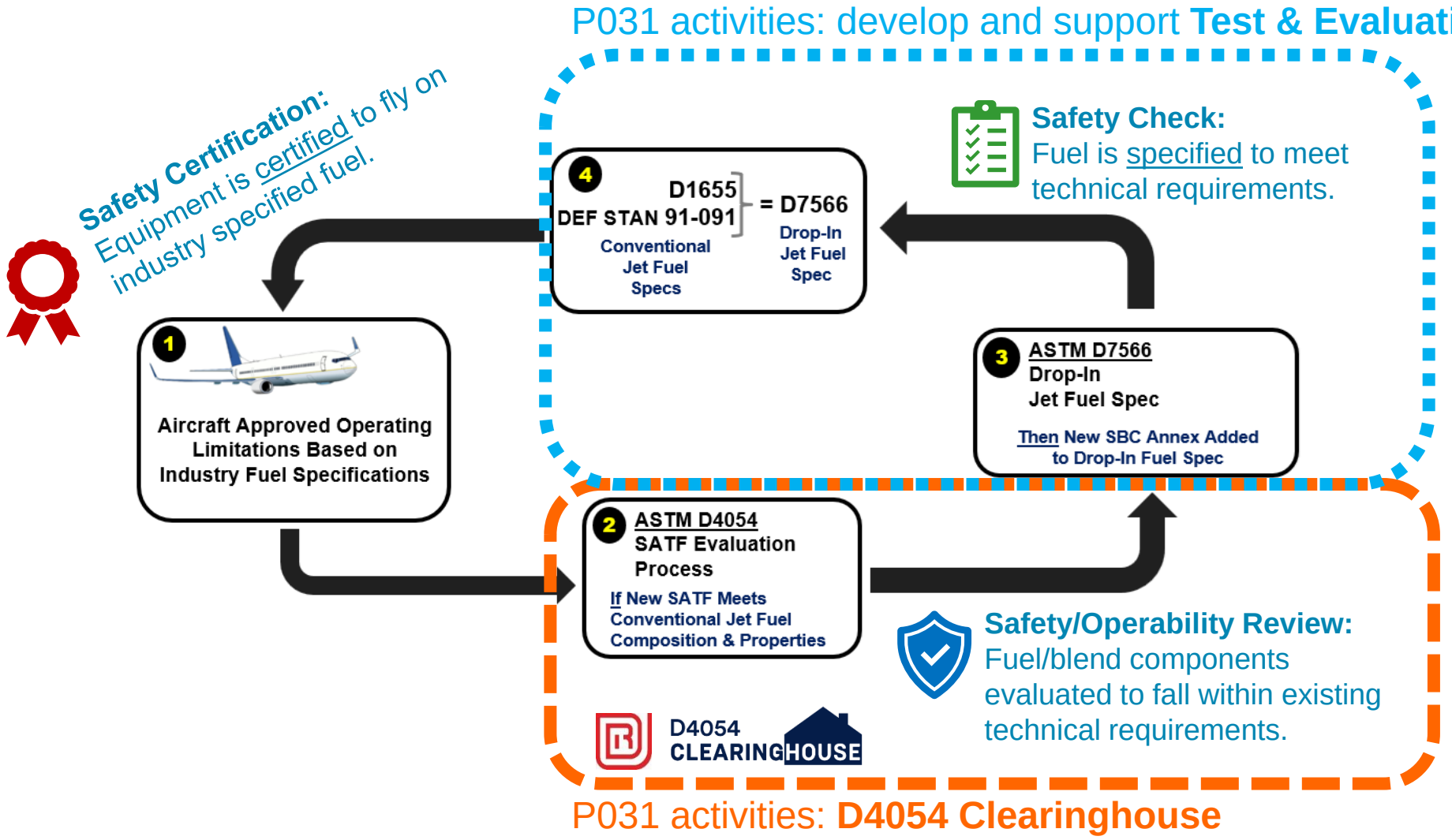
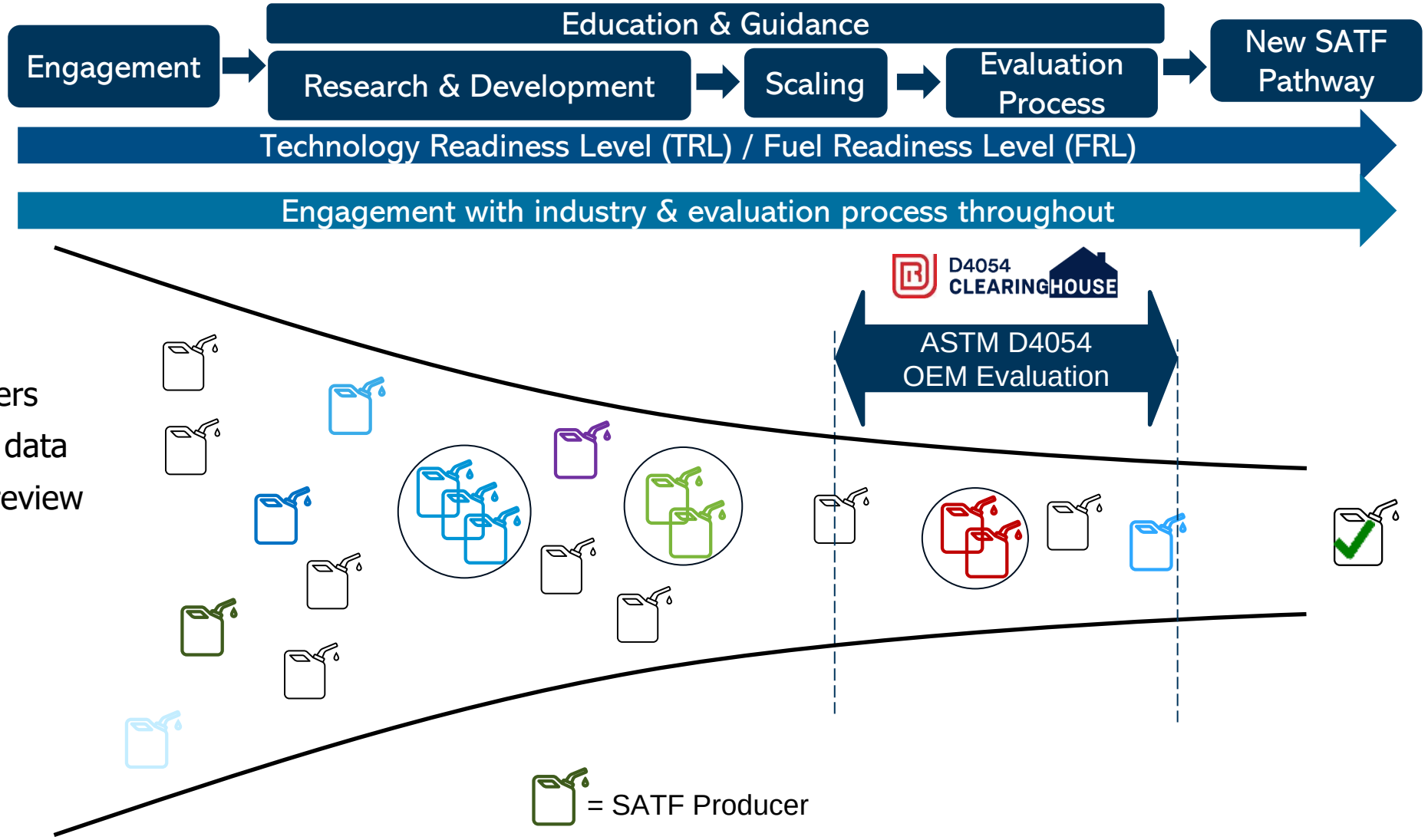
Motivation: Enable Safe and Reliable Synthetic Aviation Turbine Fuels (SATF)



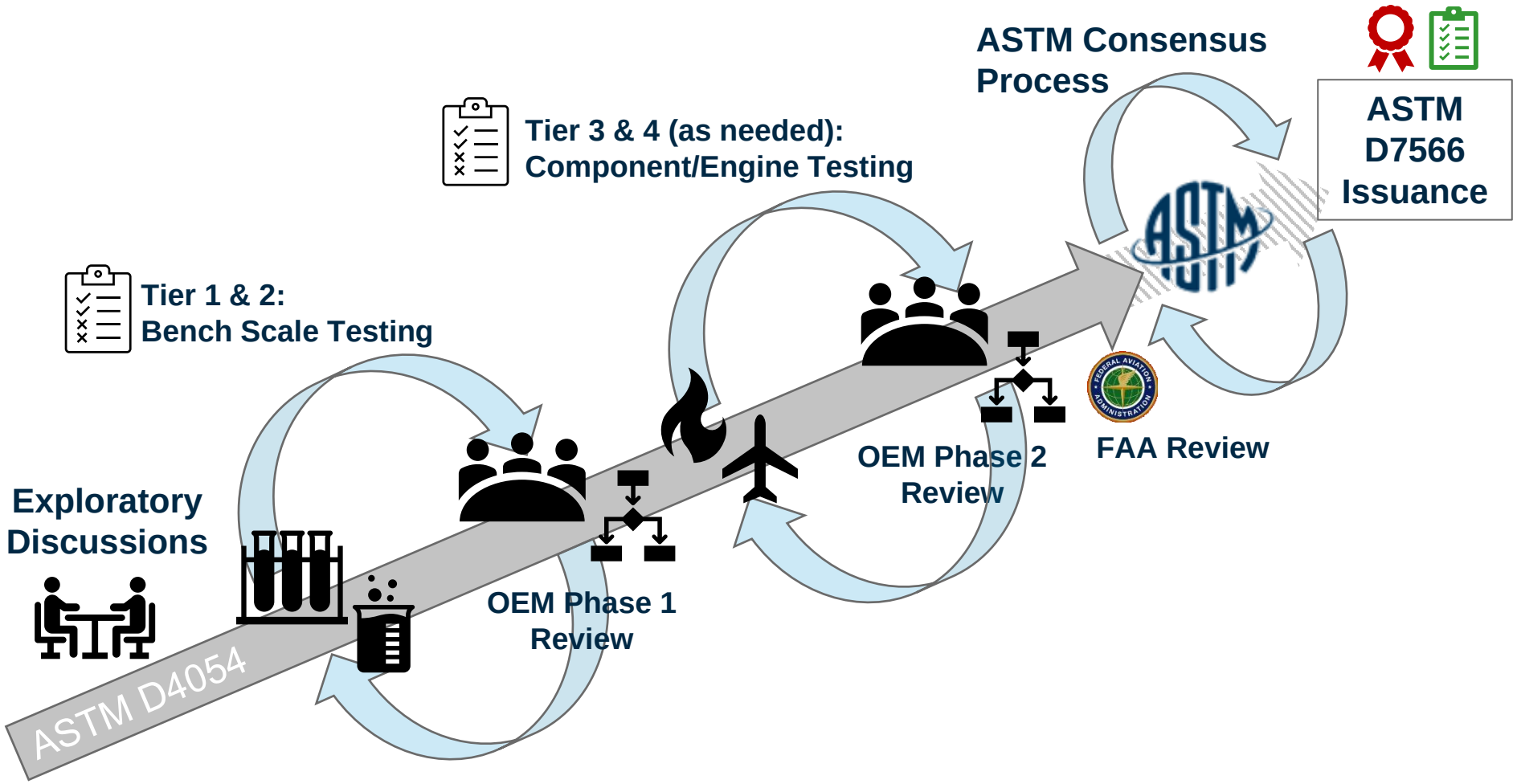
Clearinghouse: Approach



Approach

- Prepare producers
- Provide reliable data
- Facilitate OEM review

ASTM D4054 Evaluation Process



D4054 CLEARINGHOUSE

Developing Data Package for Informed Technical Decisions

ASTM D4054 Tier 1 & 2

Test Description	Method	Sample
Thermal Stability	ASTM D3241	
Setpoint Temperature 325 C		SBC
Setpoint Temperature 260 C		Blend
Thermal Stability Breakpoint (JFTOT)	ASTM D3241	Blend
Metals - Trace- ICP-MS	UDR FC-M-107	SBC & Blend
Electrical Conductivity	D2624/IP 274	SBC & Blend
Dielectric Constant vs Density	IP 638	SBC & Blend
Air Solubility (oxygen/nitrogen)	UDR FC-M-103	Neat + Blend
Preliminary materials compatibility (Nitrile, Fluorosilicone, Fluorocarbon (Viton) Elastomers	D4054 Annex 3 (optical dilatometry)	SBC & Blend
Hydrocarbon composition	UDR FC-M-101	SBC & Blend
Trace materials - Organics	UDR FC-M-102	SBC & Blend
Paraffins, Cycloparaffins, Aromatics	ASTM D2425	SBC & Blend
Simulated Distillation	ASTM D2887	SBC & Blend
Density (recommendation -20, 15, 20, 60 C)	ASTM D4052	SBC & Blend
Viscosity (recommendation -40, -20, 25, 40 C)	ASTM D7042	SBC & Blend
Freezing Point	ASTM D5972	SBC & Blend
Acidity	ASTM D3242	SBC & Blend
Physical Distillation	ASTM D86	SBC & Blend
Carbon and Hydrogen Mass	ASTM D5291C	SBC & Blend
Aromatics	ASTM D6379	SBC & Blend
Nitrogen Content	ASTM D4629	SBC & Blend
Flash Point	ASTM D93	SBC & Blend
Net Heat of Combustion	ASTM D4809	SBC & Blend
Smoke Point Naphthalenes (if smokepoint <25mm)	ASTM D1322 ASTM D1840	SBC & Blend
Copper Strip (2h@100C)	ASTM D130	SBC & Blend
Total Halogens (Fluorine, Chlorine)	ASTM D7359	SBC
Existent Gum	ASTM D381 or IP 540	SBC & Blend
MSEP (Microseparometer Index)	ASTM D3948	SBC & Blend
Lubricity (BOCLE)	ASTM D5001	SBC & Blend
Mercaptan Sulfur	ASTM D3227	SBC & Blend
Carbon and Hydrogen Mass	ASTM D5291C	SBC & Blend
Sulfur Content	ASTM D5453	SBC & Blend
FAME	IP 585	SBC & Blend
True Vapor Pressure vs Temperature	ASTM D6378	SBC & Blend
Response to Lubricity Improver	ASTM D5001	SBC & Blend
Specific Heat vs Temperature	ASTM E2716	SBC & Blend
Surface Tension vs Temperature	ASTM D1331A	SBC & Blend
Isentropic Bulk Modulus vs Temperature	FED STD 791, Method 7507	SBC & Blend
Thermal Conductivity vs Temperature	ASTM D7896	SBC & Blend
Water Solubility vs Temperature	ASTM D6304	SBC & Blend
Dielectric Constant vs Density	ASTM D924	SBC & Blend
Electrical Conductivity and Response to Static Dissipator	ASTM D2624	SBC & Blend
Storage Stability - Peroxides	ASTM D3703	SBC & Blend
Storage Stability - Potential Gum	ASTM D5304	SBC & Blend
Flammability Limits	ASTM E681	SBC & Blend
Autoignition Temperature	ASTM E659	SBC & Blend
Hot Surface Ignition Temperature	ISO 20823	SBC & Blend
Derived Cetane Number	ASTM D6890	SBC & Blend
Additive compatibility	ASTM D4054 A2.2	SBC & Blend

- Tier 1 & 2: ~50 test methods (hundreds of data points)
- Used by OEMs to evaluate safety & reliability
- Used by Producers (and ASTM committee) to draft specifications

Impacts

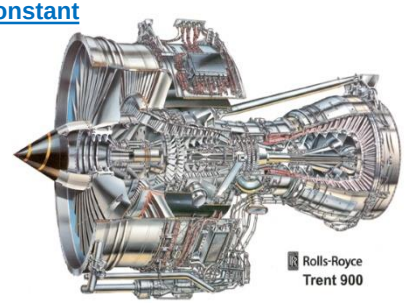
Fuel Atomization
Freezing Point, Viscosity
Distillation, Thermal Stability, Surface Tension

Fuel Metering
Density

Fuel Pumping
Freezing Point, Viscosity
Distillation

Fuel Gauging
Density, Dielectric Constant

Durability
Thermal Stability
Lubricity
Acidity
Exist Gum



Aircraft Range
Net Heat of Combustion, Density

Cold Start & Alt re-light
Flash Point, Heating Value
Distillation, Viscosity

Heat Exchangers
Specific Heat, Thermal Conductivity

Hot-End Life
Thermal Stability, Acidity
Aromatics, Sulphur

Material Compatibility
Aromatics, Acidity, Copper Strip, Trace Elements

Emissions
Aromatics, Sulphur
Distillation

Deposition (coking)
Thermal Stability, Gum, Distillation, Trace Elements

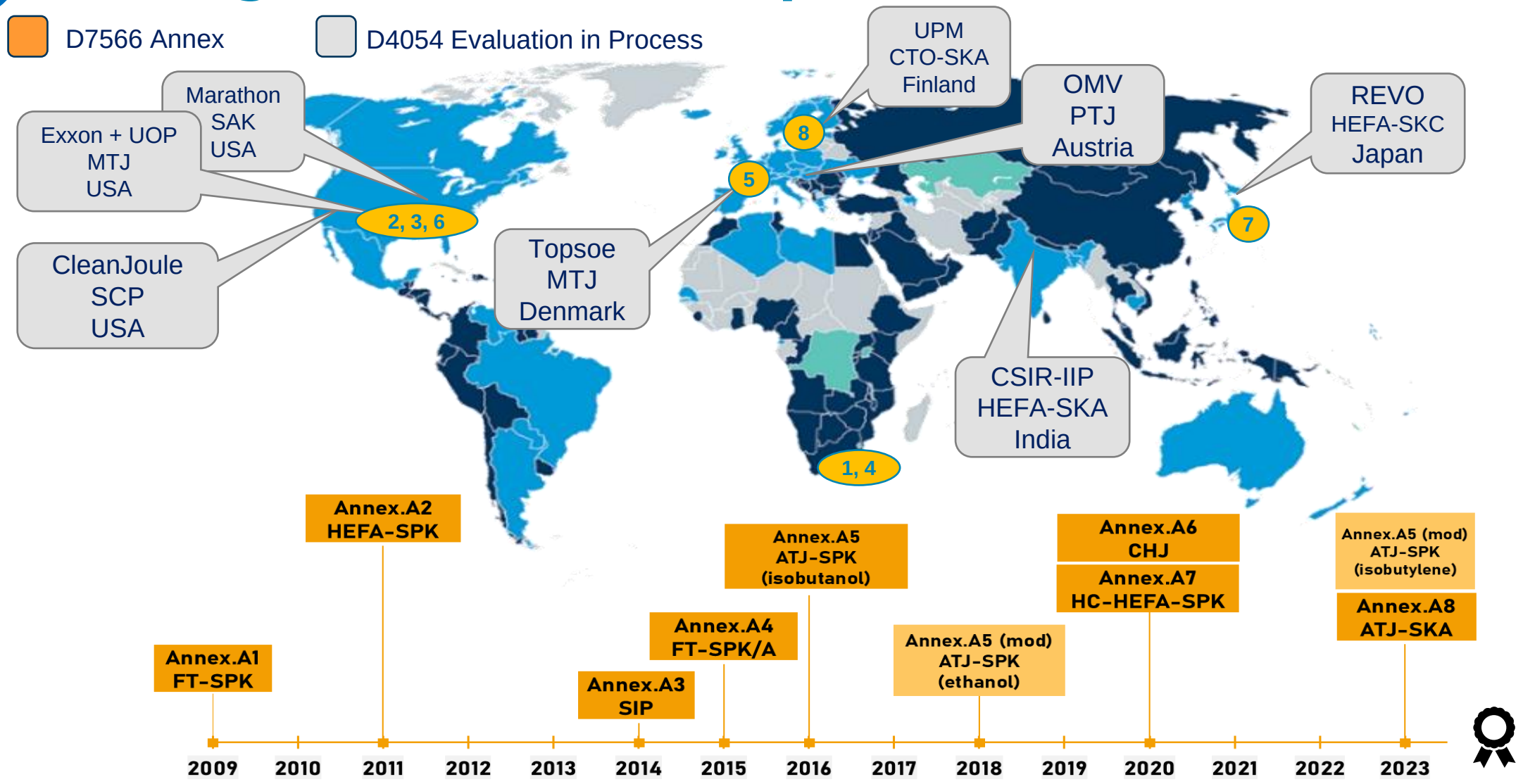
Servo Mechanisms
Bulk Modulus

Handling Safety
Flash Point, Auto-ignition, Flame Speed, Electrical Conductivity

Clearinghouse: Recent Accomplishments

Actions (Since Apr '25)	Impacts
15+ Producer interactions	• Educated 11+ producers about D4054 process, D7566 qualification, & navigating technical requirements for their unique initiatives • 3 new producers working to supply sample to Clearinghouse for evaluation
11 OEM technical review panel sessions	Made progress/advancements towards the following activities: • ASTM D1655 Generic CoProcessing • ASTM D7566 MTJ-SPK Annexure • HEFA-SKA (CSIR-IIP) pathway development • MTJ-CKA pathway development • Tire-pyrolysis oil (TPO) pathway

Clearinghouse: Prior Accomplishments & Current Efforts



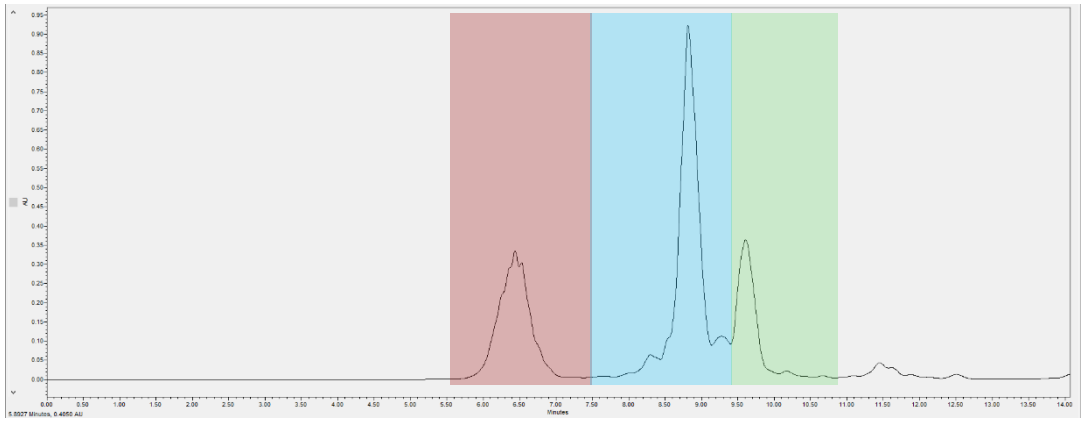
Test & Evaluation: Approach & Recent Accomplishments

- Approach:
  - Understand industry needs via stakeholder interactions at ASTM, CRC, IASH, etc…
  - Determine technical gaps and shared questions
  - Develop relevant solutions

Actions (Since Apr '25)	Impacts
ASTM D6379 Interlaboratory Study (ILS) Participant	• Data contribution assists with robustness assessment of method details • Leveraged samples to demonstrate equivalency between D6379 and FCM-101/FED STD 791 Method 7508 → increased accessibility to relevant methods
ASTM D2425 Robustness Study Participant [On Going]	• Anticipate improved understanding for D6379 pre-separation implementation → will share learnings with aviation community

Test & Evaluation: ASTM D6379 Interlaboratory Study (ILS)

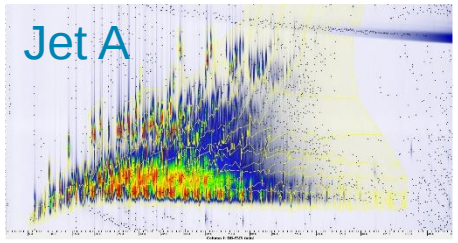
- ASTM D6379 is standard test method (STM) used in specifications to quantify saturates, monoaromatics and diaromatics via high performance liquid chromatography with refractive index detection (HPLC-RI)

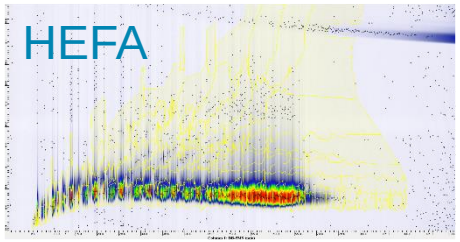


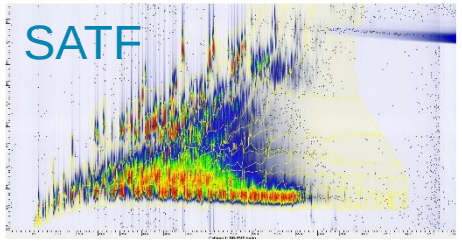
- UDRI participated in recent ILS to update method precision statement
  - 48 samples (included jet, SATF, & other distillate products)

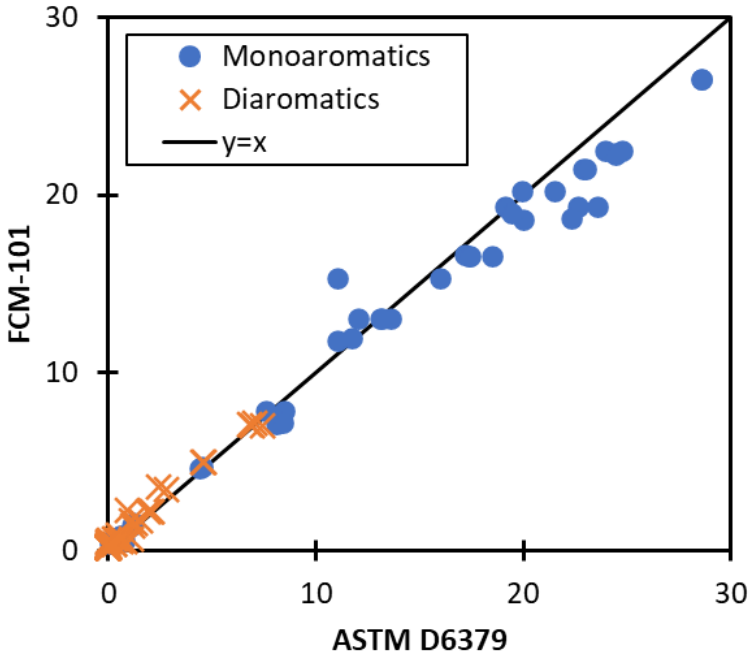
Test & Evaluation: ASTM D6379 ILS Results

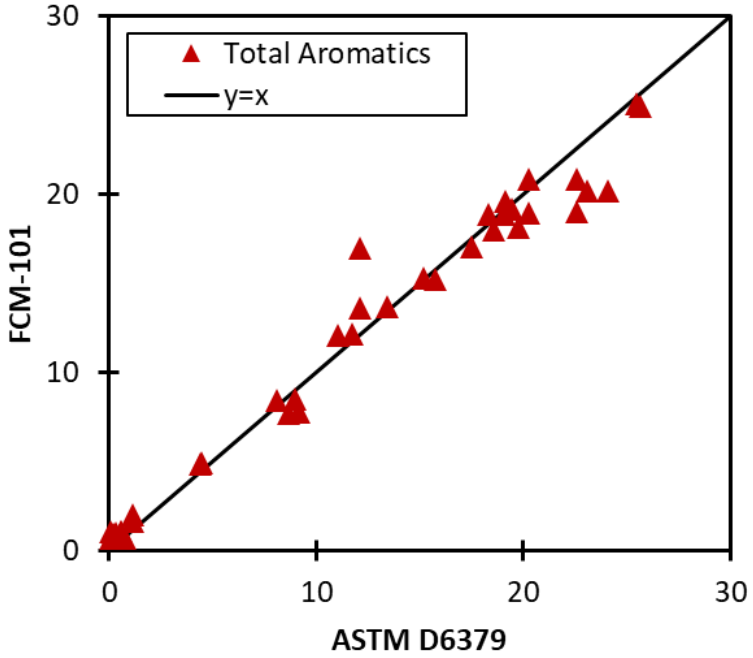
- Leveraged samples to compare equivalency of GCxGC (FCM-101)
- Preliminary results show favorable comparison regardless of sample
  - Confirms prior findings: Striebich et al., *Energy & Fuels*, 2014 doi.org/10.1021/ef500813x

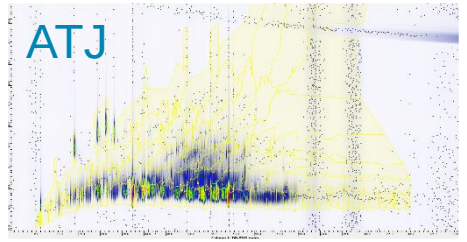


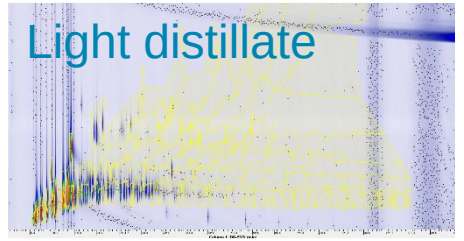












Test & Evaluation: ASTM D2425 Pilot Study

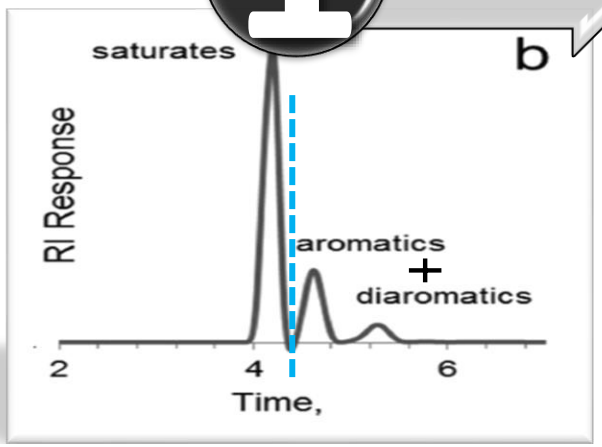
Hydrocarbon Types in Middle Distillates

- ASTM Standard Test Method (STM) D2425 used in D7566 to quantify hydrocarbon types
- Multiple challenges with the method: current pilot study investigating variability with Pre-Separation step

Pre-Separation

1

- **LC Method: D6379**
- Quant fractions



Data Acquisition

2

- Two injections to GC-MS
- Straight forward

- 70 eV electron (impact) ionization
- Scan mode, 50-300 AMU

Post Analysis

3

- Quant by summing parent and fragment ions
- Complicated math

Characteristic Mass Groupings

Peaks Read	Hydrocarbon Types
∑71 = 71, 85	paraffins
∑67 = 67, 68, 69, 81, 82, 83, 96, 97	cycloparaffins, mono or noncondensed cycloparaffins
∑123 = 123, 134, 137, 138 up to 249, 250	condensed dicycloparaffins
∑149 = 149, 150, 163, 164 up to 247, 248	condensed tricycloparaffins
∑91 = 91, 92, 105, 106 up to 175, 176	alkylbenzenes
∑103 = 103, 104, 117, 118, up to 187, 188	indan or tetrains, or both
∑115 = 115, 116, 129, 130 up to 185, 186	C_nH_{2n-10} (indenes, etc.)
∑128 = poly 128 pk	naphthalene
∑141 = 141, 142, 155, 156 up to 239, 240	naphthalenes
∑153 = 153, 154, 167, 168 up to 251, 252	C_nH_{2n-14} (acenaphthenes, etc.)
∑151 = 151, 152, 165, 166 up to 249, 250	C_nH_{2n-16} (acenaphthylenes, etc.)
∑177 = 177, 178, 191, 192 up to 247, 248	tricyclic aromatics

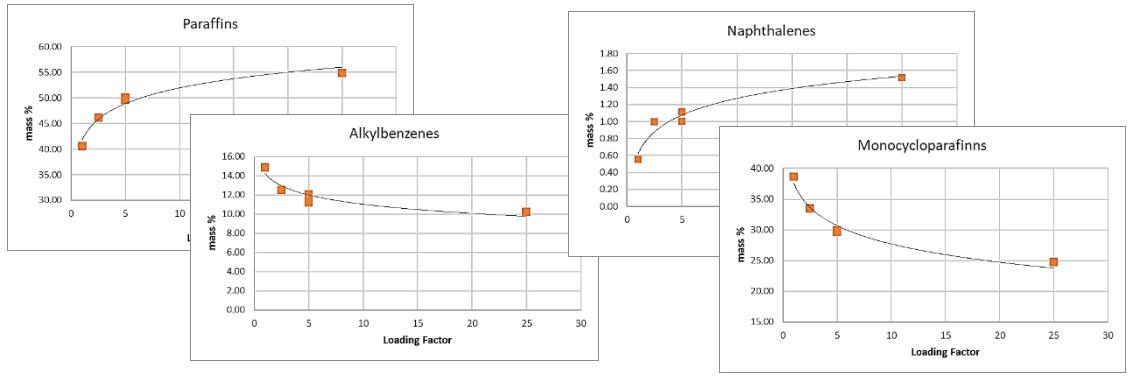
dx.doi.org/10.1021/ef500813x | Energy Fuels **2014**, 28, 5696−5706

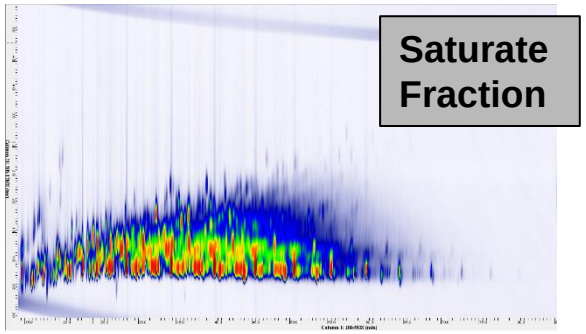
Test & Evaluation: D2425 Pilot Study—Current Investigation

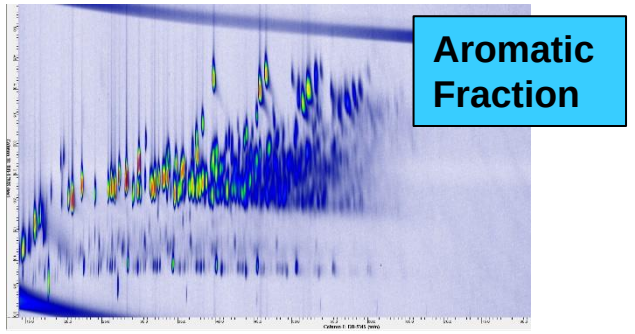
Performed HPLC pre-fractionation (modified D6379) improvements:

- Additional column → more separation
- Optimized "loading factor" (amount of sample) → better separation
- Optimized fractionation timing → minimize coelution

- Plan: report effort to ASTM D02.04 working group Dec '25







Summary

- UDRI Clearinghouse and Test & Evaluation efforts ongoing
  - Both strongly work towards enabling safe and reliable Synthetic Aviation Turbine Fuels (SATF)
- Next steps:
  - Continue Clearinghouse operations
  - Report D2425 efforts
  - Identify additional test & evaluation areas
- Key challenges/barriers
  - Community understanding of ASTM specifications, e.g., D1655, D7566, and D4054
    - Highly technical documents with specific language → often misinterpreted/miscommunicated
  - What would you like the Advisory Board to help you with or provide comment on?
    - **List of current manufactures for ASTM D7566 synthetic blending component (SBC) material**

Clearinghouse Collaboration

- UDRI Clearinghouse working closely with UK and EU Clearing houses
- Active areas of collaboration:
  - D4054 Standardization Study (internal data audit)
  - D4054 Research Report Template
  - D4054 Process Improvements
  - Establish an online OEM portal
  - Develop SATF producer resources (presentation template & coaching)

Acknowledgements

- FAA AEE for sponsorship & oversight—Bahman H., Ana G., & Anna O.

Participants

- UDRI Fuel Science Group Members: Carlie Anderson, Amanda Arts, Maria Baker, Shane Kosir, Susan Mueller, Linda Shafer, Willie Steinecker, Jim Thompson, & Steve Zabarnick (retired)
- Students: CJ Nesbit & Taylor Nicely

D4054 CLEARINGHOUSE

For more information on the US—Clearinghouse operations please contact:

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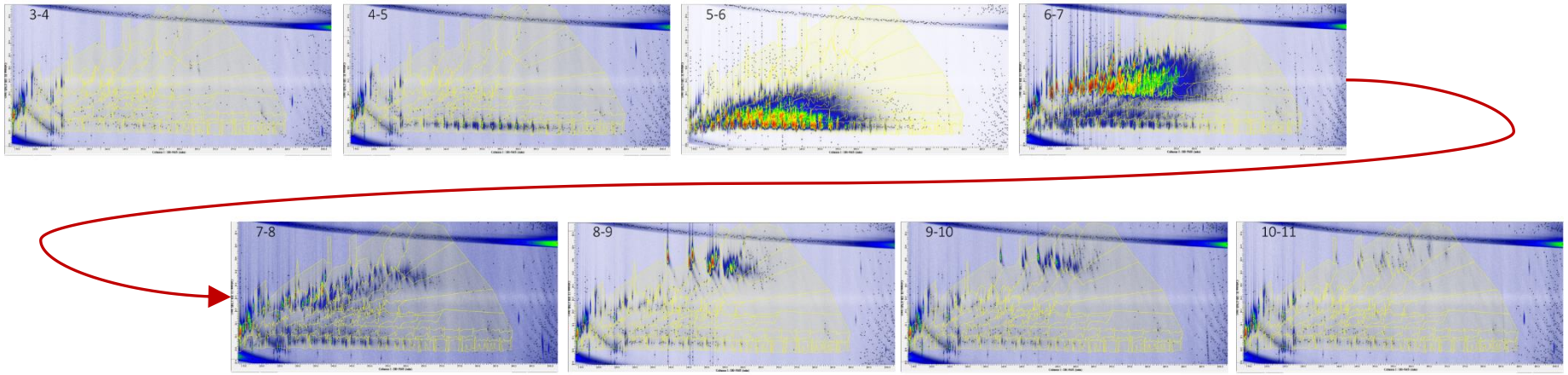
Group Leader, Fuel Science
Fuels & Combustion Division

BACKUP

D2425 Pilot Study: Pre-Separation Methods

- UDRI uses modified D6379 method for pre-separation
  - Involves using HPLC + fraction collector
- Optimized fraction collection (verified using GCxGC)



- Plan to provide data to ASTM D02.04 coordinators
  - Work towards method improvements for aviation industry

Current Candidates (1/2)

- **Marathon** (USA) – synthesized aromatic kerosene (SAK)
  - Feedstock: commercial sugars | Process: hydrodeoxygenation
  - SBC Product: 95+% monoaromatics
- **CSIR-IIP** (India) – synthesized kerosene with aromatics (SKA)
  - Feedstock: FOG | Process: adapted HEFA
  - SBC Product: SPK with ~6-10% monoaromatics
- **OMV ReOil** (Austria) – synthesized kerosene with aromatics (SKA)
  - "Plastic-to-Jet", approved for D4054 Fast Track process (<10% blend limit)
  - Feedstock: waste plastic | Process: pyrolysis oil + refinery ops
  - SBC Product: 4-10% monoaromatics, balance n-,iso-,cyclo-paraffins
- **Revo** (Japan) – HEFA with higher cycloparaffins
  - Feedstock: FOGs | Process: HEFA
  - SBC Product: SPK with 40-50% cycloparaffins

Current Candidates (2/2)

- **Methanol-to-Jet (MTJ)** – ExxonMobil/Honeywell UOP/Halder-Topsoe
  - Feedstock: Methanol | Process: dehydrogenation + oligomerization
  - SBC Products: 1) SPK and 2) CPK with >75% cycloparaffins
  - Seeking two different ASTM ballot pathways
- **CleanJoule** (USA) – cycloparaffinic kerosene (CPK)
  - Feedstock: Isoprene | Process: oligomerization + hydroprocessing
  - SBC Product: single carbon number CPK
- **UPM** (Finland) – synthesized kerosene with aromatics (SKA)
  - Feedstock: Crude Tall Oil (CTO) | Process: hydroprocessing + fractionation
  - SBC Product: <10% aromatics, balance n-, iso-, and cyclo-paraffins
- **Shell IH^2** (US) – CPK-0
  - Step 5: Tier 3-4 testing requested [PRODUCER ACTIVITY ON HOLD]
  - Feedstock: wood/cellulous | Process: hydropyrolysis + hydroconversion
  - SBC Product: ~100% cycloparaffinic