

FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

# Alternative Jet Fuel Test Database Library

## Project 33

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# Introduction: Alternative Jet Fuel Test Database



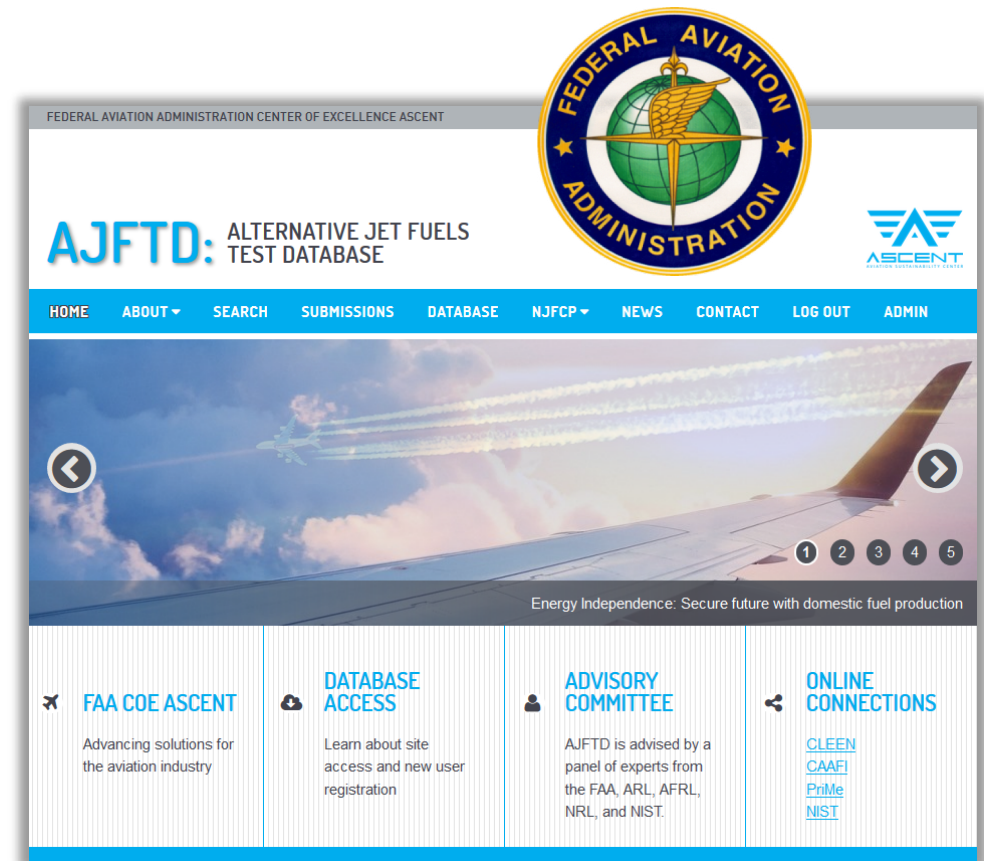
## COE Alternative Jet Fuels & Environment

- Program Manager: Cecilia Shaw
- Former Graduate Student: Anna Oldani

## A foundational database of current & emerging alternative jet fuels

- **Integrate jet fuel data** into comprehensive, common archive
- **Centralize AJF development knowledge** to aid in design and certification of new jet fuels
- **Support alternative fuels research** and certification for national and international policies and multi-stakeholder initiatives
- **Increase accessibility** to fuel testing data and approval reporting to support nascent industry

**Over 25,000 fuel records to date**



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# Focus on Critical Fuel Property Data



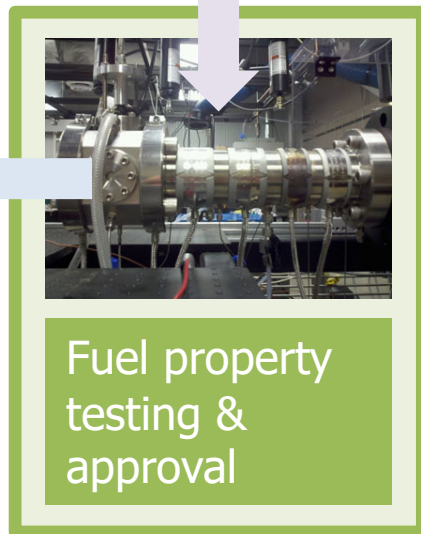
Feedstock production & logistics



Conversion, scale-up & processing



End use production & emission testing




Fuel property testing & approval


[altjetfuels.illinois.edu](http://altjetfuels.illinois.edu)

Phase I: Web Portal & Data Population  
Phase II: Database Conversion  
Current database addresses critical fuel testing stages of certification process

  
*Easily access, quickly query* large dataset

  
*Flexible analytics* and web interface (Phase II)

  
*Support* across programming languages

  
*Services*  
AJFTD DynamoDB  
JETSCREEN MongoDB



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# JETSCREEN – Fuel Database



Authors: Bastian Rauch (DLR), Simon Blakey (USFD / UoB)

Partners involved:



**Deutsches Zentrum  
für Luft- und Raumfahrt**  
German Aerospace Center



The  
University  
Of  
Sheffield.

## Objectives

- Develop a searchable database for the properties of potential alternative jet fuels. The database will contain data in addition to the standard fuel properties.
- Employ the database to support:
  - Screening (prior) and streamlining alternative aviation fuel approval process



**Alternative Jet Fuel Test Database**  
FAA COE Alternative Jet Fuels & Environment

**Jet Fuel Screening & Optimization**  
EU Horizon 2020 Research & Innovation



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723525

# Timeline

09.2017

- **NJFCP/JETSCREEN – Rome meeting**

10.2017

- **AJFTD/JETSCREEN – Discussions to Merge Database**
  - JETSCREEN → AJFTD: Fuel data schema
  - AJFTD → JETSCREEN: Access to database

12.2018

- **NJFCP/AJFTD/JETSCREEN – Paris meeting**
  - Decision to join forces and push use of fuel data to a new level
  - Define goals for joint database setup

5.2019

- **CRC Aviation Meeting 2019**
  - Introduction of Database Integration Concept

8.2019

- **IASH Meeting 2019**
  - Introduction of Data Integration Scheme and Vision

# Existing Issues & Needs

## Issues

**Uncoordinated** fuel data storage systems

- Coordinate fuel data archiving

**Inconsistent** fuel analysis records

- Facilitate airport fuel analysis reporting

**Uninformed** fuel processing/logistics systems

- Track fuel supply information

## Needs

**Integrated** data & dissemination

- Link upstream JETSCREEN-AJFTD

**Archiving** of fuels in use

- Archiving of actual fuels in use (real time)

# Identified Targets



## Common Data Schema – non relational format

- Include Tier 2, 3, and 4 properties, life cycle assessment, and impact on system components
- Need to understand **complexities of extended data sets** beyond standardized Tier 1 testing
- Assess ability to incorporate novel analysis methods (GC x GC)

## Integrate Databases

- Identify **currently available databases** housing fuel test method evaluations
- Include measurement uncertainties of applied testing methods
- Detailed **global fuel dataset** under common schema for conventional, alternative, and blends

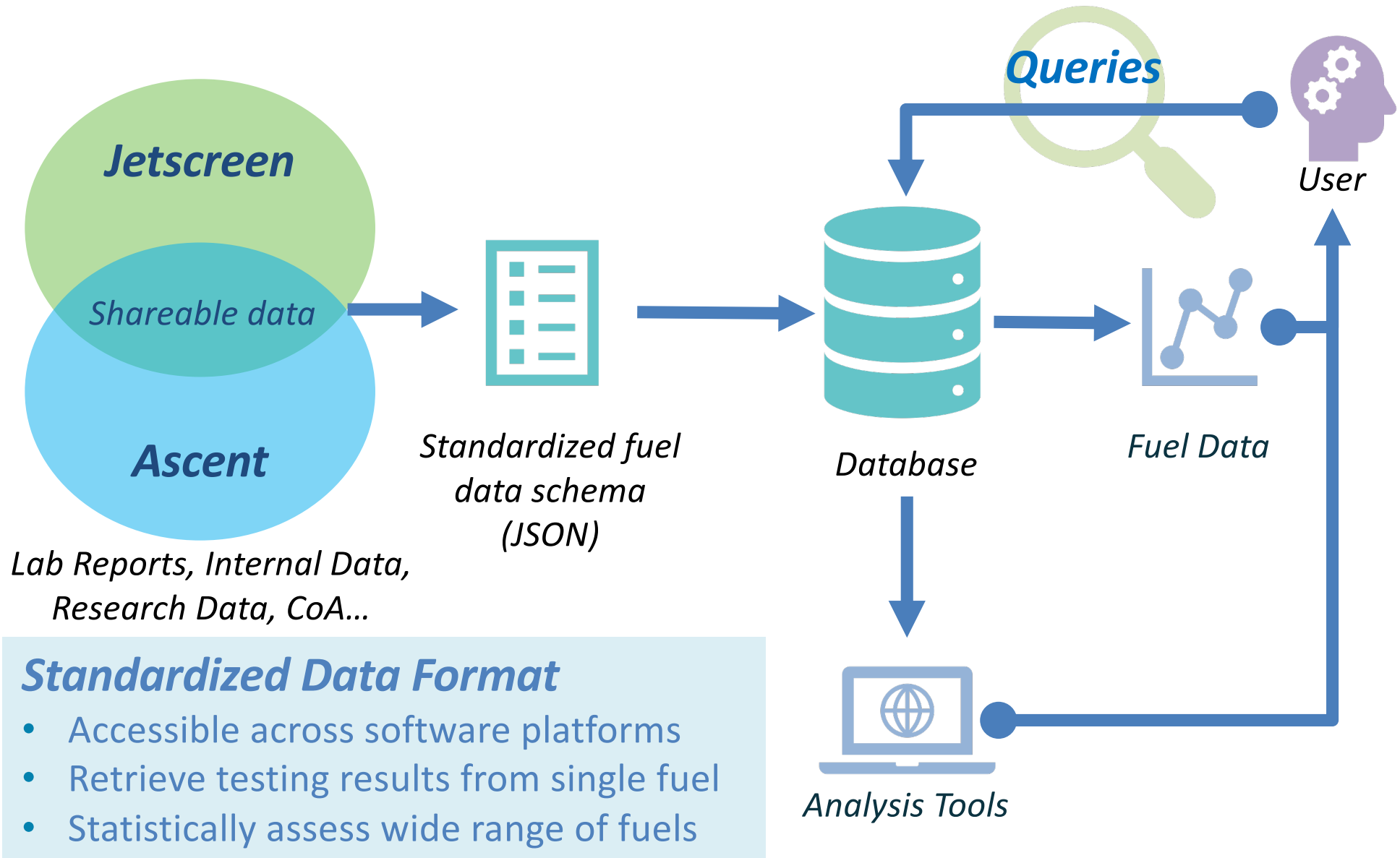
## Maintain Proprietary Datasets

- **Common interface**, maintain distinct backends (MongoDB, DynamoDB)
- Different access levels by user group

## Develop and Apply Analysis Tools

- **Specialized analysis tools** based on programming platform and user needs
- Employ specification property, performance, and/or end-use/emissions targeted tools

# Collaborative DB Architecture



## Standardized Data Format

- Accessible across software platforms
- Retrieve testing results from single fuel
- Statistically assess wide range of fuels



# Unify Disparate Data

**GCxGC Summary**  
neat injection  
analyzed: 01-08-14  
JP-8

Hydrogen content (weight %)	14.1
Average Molecular Wt (g/mole)	157

POSF-5699

	Weight %	Volume %
<b>Aromatics</b>		
<b>Alkylbenzenes</b>		
benzene (C06)	<0.01	<0.01
toluene (C07)	0.08	0.07
C2-benzene (C08)	0.63	0.57
C3-benzene (C09)	3.21	2.91
C4-benzene (C10)	3.91	3.56
C5-benzene (C11)	2.63	2.38
C6-benzene (C12)	1.80	1.64
C7-benzene (C13)	1.08	0.98
C8-benzene (C14)	0.63	0.58
C9-benzene (C15)	0.22	0.20
C10-benzene (C16+)	0.06	0.06
<b>Total Alkylbenzenes</b>	<b>14.25</b>	<b>12.89</b>
<b>Dialkyl and trialkylbenzenes, Biphenyls, etc.</b>		
diaromatic-C10	0.07	0.06
diaromatic-C11	0.27	0.21
diaromatic-C12	0.40	0.32
diaromatic-C13	0.16	0.13

**GCxGC image**

```

{
  "header":{
    "origin":"NuStar Refining, LLC",
    "description":"New batch of JP-8 for use in T-63 and S-12, remainder put into drum (13 total).\n\nCRATCAF A-1 \n testing",
    "tags":[
      "10264",
      "JP-8",
      "NuStar Refining, LLC",
      "combustion \"rules and tools\" program"
    ],
    "fuel_type":"JP-8",
    "name":"10264",
    "date_received":"2013-04-03 00:00:00",
    "quantity":"7161.0 gallon(s)"
  },
  "property":{
    "micro_distillation_residue":[
      {
        "time_stamp":"2016/08/03 15:15:00",
        "unit":"%",
        "maximum_value":1.5,
        "value":1.3,
        "test_method":"D 7345"
      }
    ],
    "density":[
      {
        "temperature_value":"15",
        "maximum_value":0.84,
        "value":0.78,
        "temperature_unit":"C",
        "test_method":"D 4052",
        "time_stamp":"2013/04/16 14:11:00",
        "unit":"kg/L",
        "minimum_value":0.775
      }
    ]
  }
}
        
```

**JSON Schema**

**Component Breakdown**

	Weight %	Volume %
<b>n-paraffins</b>		
ATJ	~10	~10
HEFA	~10	~10
HDO-SK/SAK	~15	~15
F-T	~15	~15
HDCJ	~55	~55
Blends	~20	~20
Conventional	~20	~20
<b>iso-paraffins</b>		
ATJ	~95	~95
HEFA	~85	~85
HDO-SK/SAK	~75	~75
F-T	~75	~75
HDCJ	~40	~40
Blends	~45	~45
Conventional	~25	~25
<b>cycloparaffins</b>		
ATJ	~25	~25
HEFA	~25	~25
HDO-SK/SAK	~25	~25
F-T	~55	~55
HDCJ	~20	~20
Blends	~35	~35
Conventional	~35	~35
<b>aromatics</b>		
ATJ	~65	~65
HEFA	~40	~40
HDO-SK/SAK	~15	~15
F-T	~40	~40
HDCJ	~15	~15
Blends	~20	~20
Conventional	~20	~20

Enables enhanced fuel comparison capabilities

# Impact 1: Screening & Safety



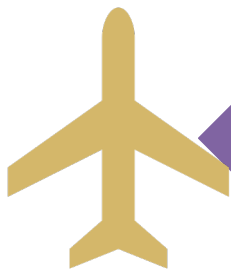
*Develop screening guides* to assess new fuels

- Accelerate approval through early-stage pre-screening
- Assist fuel producers with access to AJF property data



*Coordinate fuel data* with global aviation data

- Track flight & aircraft system issues with fuel supply data
- Investigate fuel-related system or component failures



*Expand fuel & flight data* records

- Connect AJF blend & flight data (maintenance, emissions,..)
- Demonstrate AJF safety & compatibility in current systems
- Increase market support for continued AJF integration



**Requires data on actual fuels used**

# Enhanced Fuel Screening

Fuel specification	Min	Max	Fuel Sample	Whisker Chart
Colour			30	
Acidity (mg KOH/g)	0	0.015	0.002	
Aromatics IP 156 (%vol)	0	25	1.8	
Sulphur (%mass)	0	0.3	0.018	
Mercaptan (%mass)	0	0.003	0	
IBP (degC)			148.8	
10% (degC)		205	169.8	
50% (degC)			198.7	
90% (degC)			235.1	
FBP (degC)		300	251.9	
Flash point (degC)	38		41.5	
Density @15degC (kg/m3)	775	840	759.6	
Freezing point (degC)		-47	-59	
Viscosity @-20degC (cSt)	0	8	3.885	
Smoke point (mm)	5		50	
Naphthalenes (%vol) if SP > 25mm		3	0	
Specific Energy (MJ/kg)	42.8		44.023	
Existent Gum (mg/100 ml)		7	1	
MSEP	85		99	

A new fuel, some properties within spec, but outside experience:

Solid lines represent distribution of the conventional fuels in the database

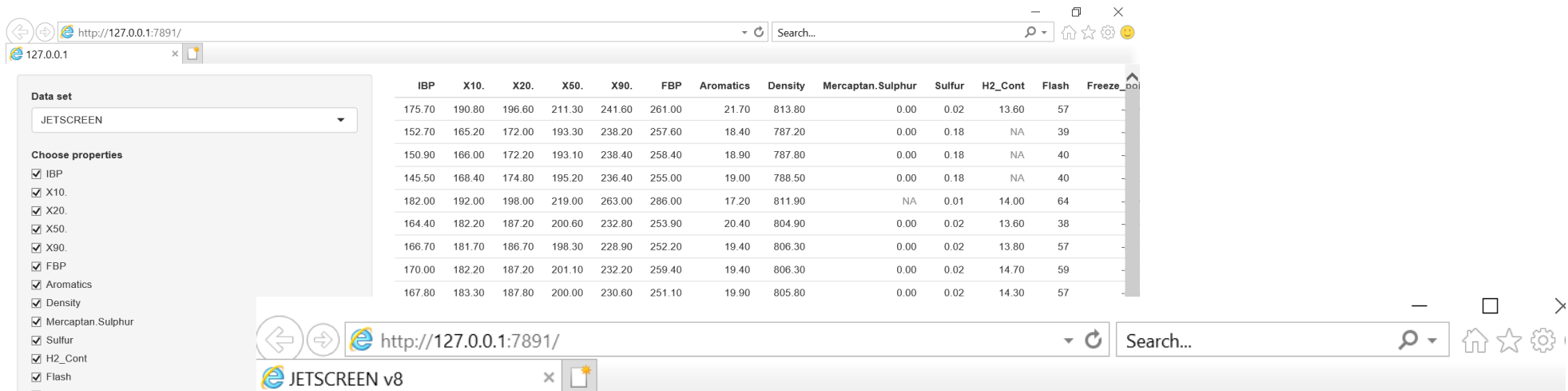
Dashed lines represent the limits of the specification

Properties within specification, and within range of fuels already in use

Properties outside of specification

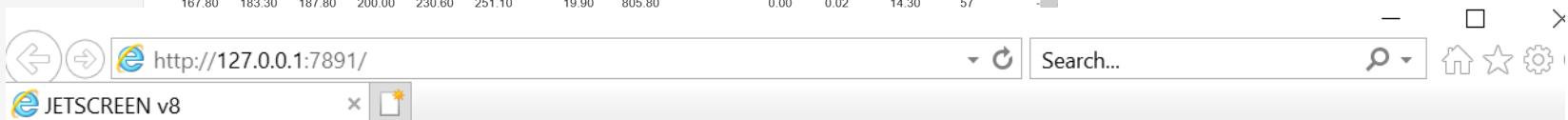
Properties outside of norm, but within specification

# Online access to JETSCREEN data



The screenshot shows the JETSCREEN v8 web application interface. On the left, there is a sidebar with a 'Data set' dropdown menu set to 'JETSCREEN' and a 'Choose properties' section with a list of checked fuel properties: IBP, X10, X20, X50, X90, FBP, Aromatics, Density, Mercaptan.Sulphur, Sulfur, H2\_Cont, Flash, Freeze\_point, Viscosity, Heat.MJ.kg, Smoke\_Point, E\_Gum, MSEP, Conductivity, and Cet\_index. The main area displays a table of fuel properties for various samples.

IBP	X10.	X20.	X50.	X90.	FBP	Aromatics	Density	Mercaptan.Sulphur	Sulfur	H2_Cont	Flash	Freeze_point
175.70	190.80	196.60	211.30	241.60	261.00	21.70	813.80	0.00	0.02	13.60	57	
152.70	165.20	172.00	193.30	238.20	257.60	18.40	787.20	0.00	0.18	NA	39	
150.90	166.00	172.20	193.10	238.40	258.40	18.90	787.80	0.00	0.18	NA	40	
145.50	168.40	174.80	195.20	236.40	255.00	19.00	788.50	0.00	0.18	NA	40	
182.00	192.00	198.00	219.00	263.00	286.00	17.20	811.90	NA	0.01	14.00	64	
164.40	182.20	187.20	200.60	232.80	253.90	20.40	804.90	0.00	0.02	13.60	38	
166.70	181.70	186.70	198.30	228.90	252.20	19.40	806.30	0.00	0.02	13.80	57	
170.00	182.20	187.20	201.10	232.20	259.40	19.40	806.30	0.00	0.02	14.70	59	
167.80	183.30	187.80	200.00	230.60	251.10	19.90	805.80	0.00	0.02	14.30	57	



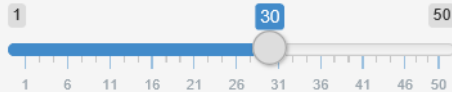
This screenshot shows the 'Fuel property' selection interface. A dropdown menu is set to 'H2\_Cont'. Below it, a 'Number of bins' slider is set to 30. The slider has a scale from 1 to 50 with major ticks every 5 units and minor ticks every 1 unit.

## JETSCREEN v8

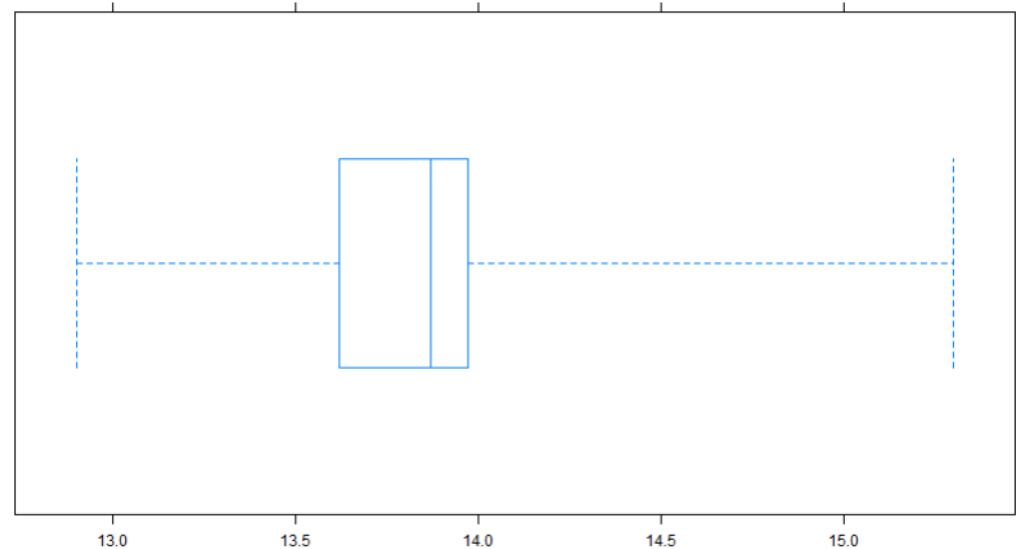
### Fuel property

H2\_Cont

Number of bins:



H2\_Cont you chose 30 and therefore PQIS\$H2\_Cont



# Gen II AJFTD Fuel Tool – Now Live



## Search Fuels

Search by Fuel ID

Search by Airport

Search by Fuel Type

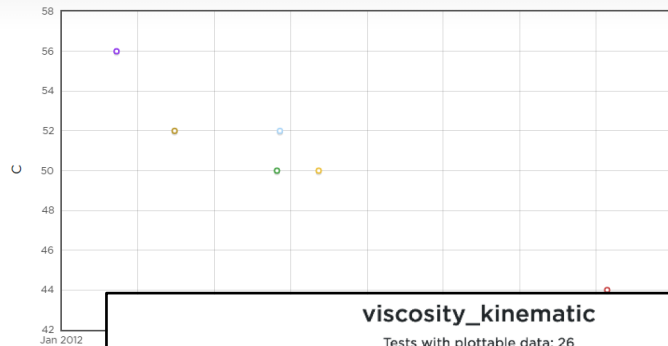
 

Fuel Name	Fuel Description		Selected Fuels
10299	Sampled 5-23-13 from Tank F-3 ATJ Prior to Delivery Bio-derived Gevo ATJ from AFRL/RQTF Tank F-3. This testing is in support of the USAF Aernative Fuel Certification Program. * As of 29 May 2013, Tank F-3 contains 10,797 gal bio-derived ATJ. Sampl	<input type="button" value="eye"/> <input type="button" value="+"/>	10299 <input type="button" value="x"/>
10373	Off-loaded into tank S-16	<input type="button" value="eye"/> <input type="button" value="+"/>	10373 <input type="button" value="x"/>
12381	HF-ETJ Boiling Range: 140-265Å° C Contact: Richard Hallen Pacific Northwest Laboratory 902 Battelle Blvd. MSIN P8-60 Richland, WA 99354 509-375-6919 richard.hallen@pnnl.gov	<input type="button" value="eye"/> <input type="button" value="+"/>	12381 <input type="button" value="x"/>
	gallons of bio-derived Gevo ATJ to AFRL/RQTF Fuels and Energy	<input type="button" value="eye"/> <input type="button" value="+"/>	8041 <input type="button" value="x"/>
	Gevo ATJ to AFRL/RQTF. This testing is in support of the USAF	<input type="button" value="eye"/> <input type="button" value="+"/>	8319 <input type="button" value="x"/>
		<input type="button" value="eye"/> <input type="button" value="+"/>	9324 <input type="button" value="x"/>

[Compare selected fuels](#)

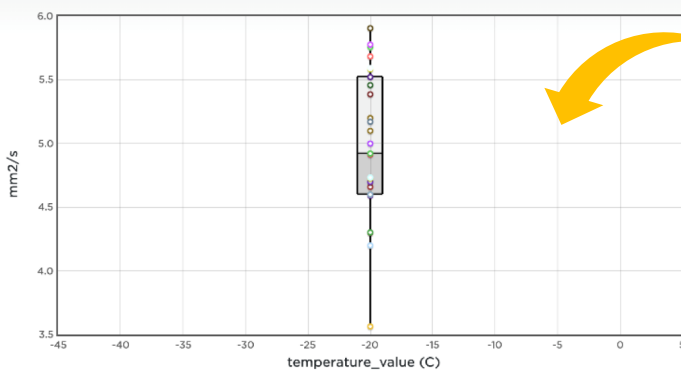
### flash\_point

Number of tests: 6  
Tests with plottable data: 6



### viscosity\_kinematic

Tests with plottable data: 26



## Select Metrics to Plot

### Properties

- copper\_strip\_corrosion
- density
- density\_api\_by\_meter
- distillation
- distillation\_loss
- distillation\_residue
- distillation\_t90-t10
- electrical\_conductivity
- electrical\_conductivity\_vs\_temperature
- filtration\_time
- flash\_point
- freezing\_point
- lubricity\_bocle
- net\_heat\_of\_combustion
- smoke\_point
- thermal\_stability\_breakpoint
- thermal\_stability\_maximum\_pressure\_drop
- thermal\_stability\_tube\_deposit\_rating
- viscosity\_kinematic
- workmanship

### Composition

- acidity\_total
- additives\_fs
- aromatics\_total
- contaminants\_existence
- contaminants\_total\_particulate\_contamination
- contaminants\_water\_coulometric\_karlischer\_titration
- contaminants\_water\_reaction\_interface\_condition
- hydrogen\_content
- msep
- olefins\_total
- sulfur
- sulfur\_mercaptan

[altjetfuels.illinois.edu](http://altjetfuels.illinois.edu)

Users can directly export data

# Impact 2: Engineering & Science

**Statistical analysis / feature detection for aircraft-related fuel properties**

- Facilitate design of aircraft components impacted by fuel properties

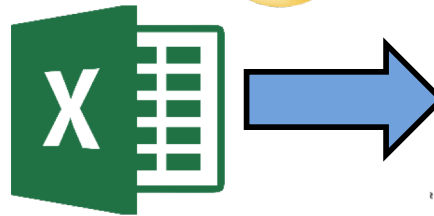
**Development & validation of statistical & physical-based models**

- Streamline approval, reduce early stage testing
- Enhance development & production of alternative fuels

# More widely...

```
{
  "test_method": "IP 564",
  "Particles": "less than 30microns",
  "unit": "counts/ml",
  "value": 2.9,
  "iso_code": 9
},
],
"property": {
  "saybolt_color": [
    {
      "test_method": "D156",
      "unit": "rating",
      "value": 26
    }
  ],
  "acidity_total": [
    {
      "test_method": "D3242",
      "unit": "mg KOH/g",
      "value": 0.004
    }
  ],
  "distillation": [
    {
      "test_method": "D86",
      "volume_evaporated_unit": "%",
      "volume_evaporated_value": 0.0,
      "volume_evaporated_unit": "C",
      "value": 156.6
    },
    {
      "test_method": "D86",
      "volume_evaporated_unit": "%",
      "value": 156.6
    }
  ]
}
}
```

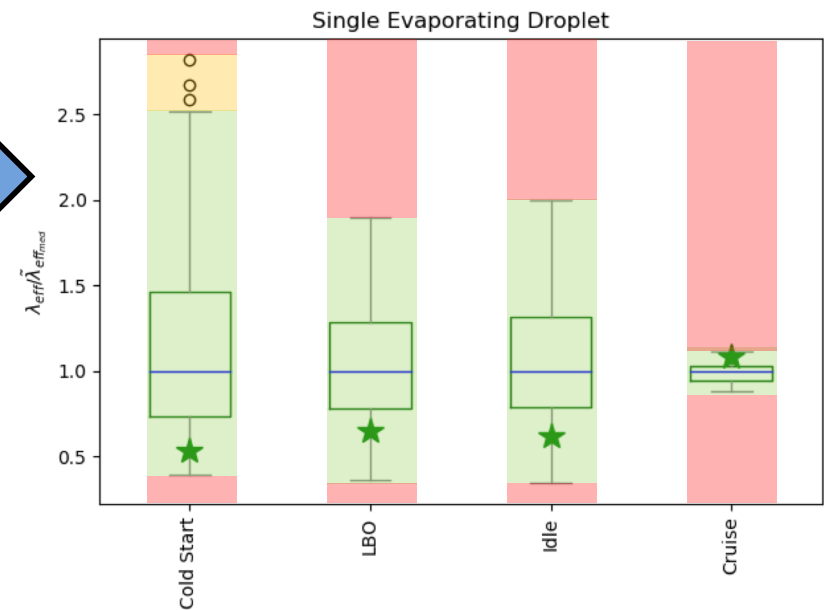
Can be read by multiple software using conversion / interpretation script



FLUENT® ...



Machine learning based analysis tools



Create tailored, reproducible output

# Impact 3: System Operations



**Track properties of fuels in use:** processing, supply chain, end use

- Improve quality control in fuel production & supply



**Increase data access** for airports & airlines

- Demonstrate safe usage of AJFs with detailed supply info
- Build trust between producers, suppliers, & consumers



**Expand operational data** compilation & dissemination

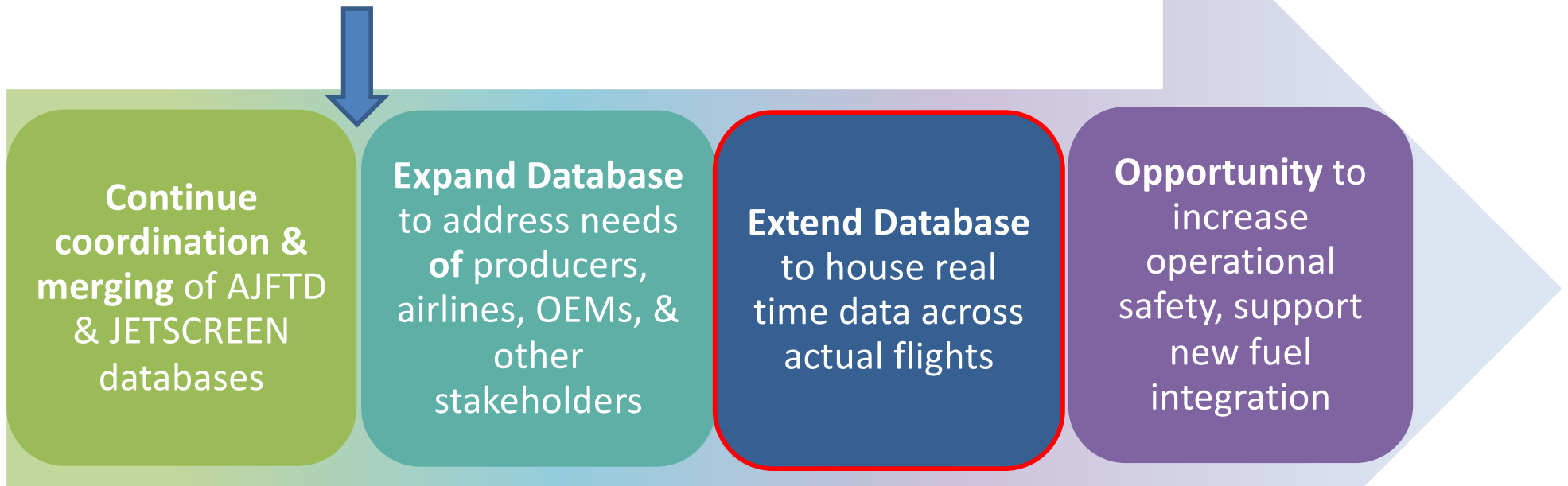
- Increase system optimization across industry

**Is actual flight fuel data logging possible?**



# Summary & Future Steps

Integration of other data from CORSEA, CAAFI, etc.



Global fuel database & tracking system

# Questions

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[s.blakey@sheffield.ac.uk](mailto:s.blakey@sheffield.ac.uk)

# Other data of interest...

- ◉ May include **CORSIA** relevant emissions data
  - ◉ Tracking fuels within the system
  - ◉ Methods for receiving / storing data need to be developed
- ◉ **CAAFI**: Pre-screening relevant data
- ◉ Include **fuel production** information (when available), LCA, etc.
- ◉ We expect **non-CO<sub>2</sub> impacts** to become increasingly important
  - ◉ Storage and information system already in place
- ◉ **Fuel data across Europe and around the globe**
  - ◉ Vision of extending connection to other databases

# Data Conversion Incentives



Accelerate data retrieval

Enable statistical analyses with robust correlations

Easily identify unusual data (misreported, outliers, ...)

Facilitate collaboration with related programs and data sharing