

# Alternative Jet Fuel Test and Evaluation

## University of Dayton Research Institute

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

## Research Approach:

Fuel property and composition testing

Support for rig/engine evaluations

Coordination of OEM approval process

Goal is new D7566 approved annex for each candidate fuel

## Objective:

**Coordinated performance testing** to support the **evaluation of novel alternative jet fuels** toward ASTM approval.

## Project Benefits:

- ASTM research reports for OEM approval and **creation of D7566 annexes**
- **Management of D4054 qualification** process
- **Coordination of fuel qualification** to enable increased supply of secure, safe, low life cycle carbon, sustainable aviation fuels (SAF)

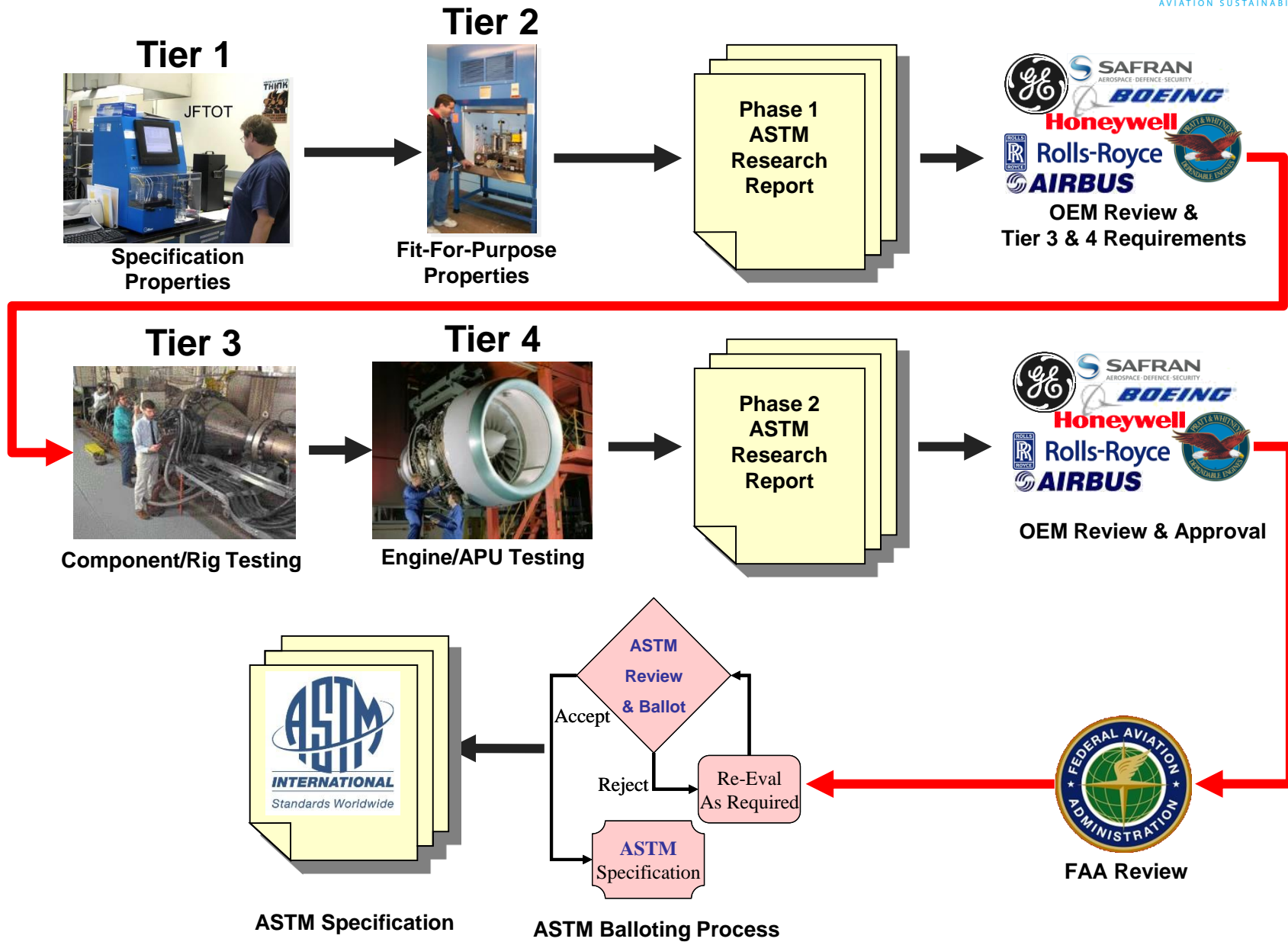
## Major Accomplishments (to date):

- ASTM D7566 Annexes – ATJ & HC-HEFA
- D4054 Fast Track Process
- Two GCxGC analysis methods documented
- Co-processing pathways in ASTM D1655
- Testing of Shell IH2, HFP-HEFA, Global Bioenergies, CSIR-IIP, Revo, and Swedish Biofuels fuels
- Cost-share with Global Bioenergies

## Future Work / Schedule:

- Continue guiding fuel producers through approval
- Continue fuel testing & evaluation
- Continue OEM committee and report reviews toward ASTM approvals

# D4054 Certification Process



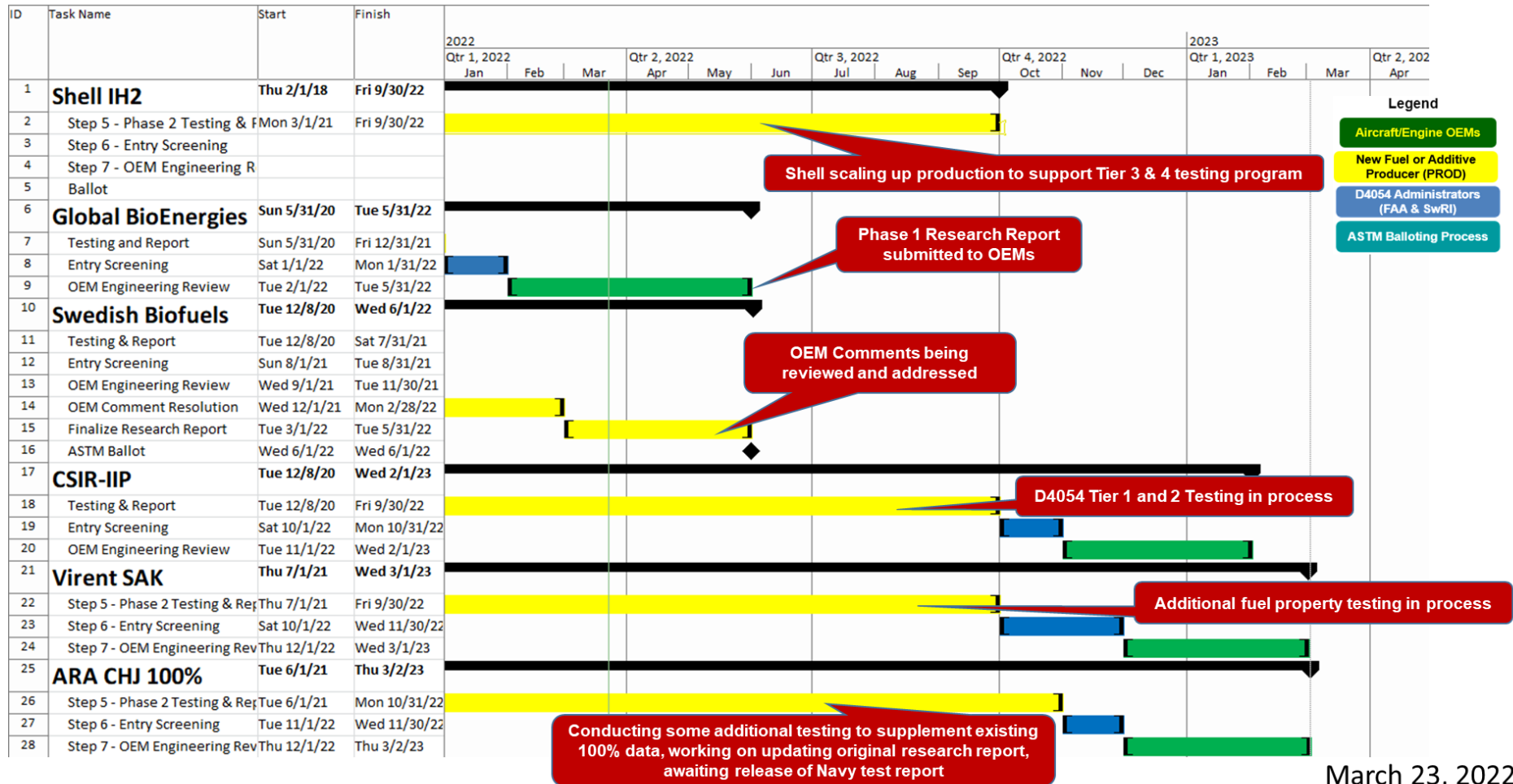
# Current Candidates



- Shell IH<sup>2</sup> – wood pyrolysis – Phase 1 completed
  - Planning for Tier 3 testing – APU & combustor rig (also CLEEN III)
  - Waiting on larger fuel volumes
- Global Bioenergies (Rewofuel) – France – wood residue to isobutylene
  - Tier 1/2 testing complete – OEM review started Jan 2022
  - GBE/EU funds for support – received €250K as cost share
- Swedish Biofuels – ATJ with variety of alcohols
  - Response provided to Phase 1 OEM panel review
- CSIR-IIP – India – single step HEFA w/ aromatics
  - completed initial Tier 1/2 testing
- Virent SAK – aromatics only blendstock – additional testing planned
- ARA CHJ – being considered for first 100% approval
- Revo – Japan – HEFA with higher cycloparaffins – Deciding on 45% cycloparaffin limit?

# Gantt Chart Schedule

## D4054 Clearinghouse Forecasted Fuel Evaluation Schedule



March 23, 2022

# New Fuel Candidates

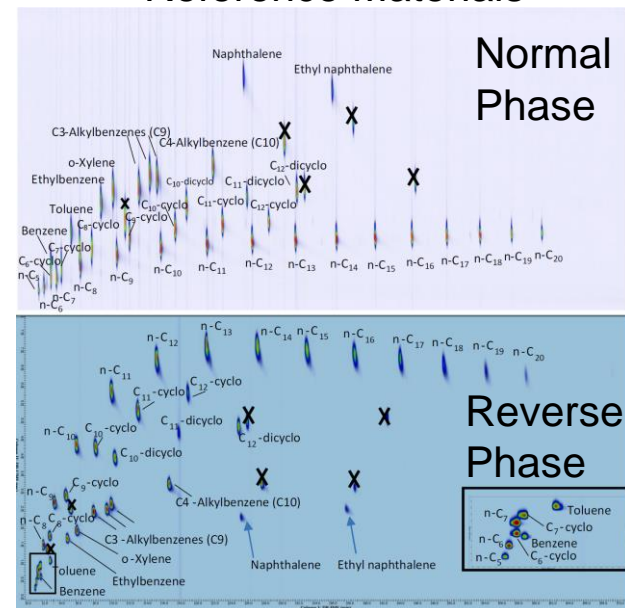
- OMV ReOil – Austria
  - Used plastics to synthetic crude
  - Initial sample 10% aromatics, high gums & FP
  - Fast Track or full (50%) approval?
- Forge Hydrocarbons – Canada
  - Lipids to hydrocarbons – with aromatics & cycloparaffins
- Prometheus Fuels – USA
  - CO<sub>2</sub> from air electrochemical conversion to alcohols using renewable energy
- Alder Energy – USA
  - NREL technology for pyrolysis oil – interested in the Fast Track
- Green Lizard – UK
  - Pyrolysis oil from wood and waste products
- Vertimass – US
  - DOE BETO, Optimization of Bio-Derived Jet Fuel Blends Funds – renewable cycloalkanes from ethanol



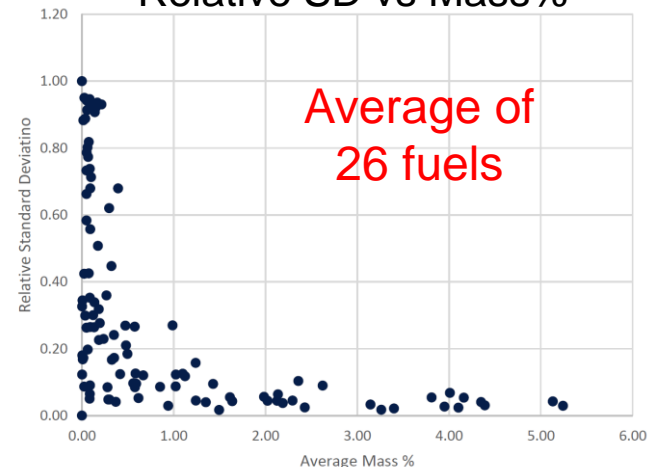
# GCxGC Methods for Alternative Fuels

- Final Report Completed
- Phase 1: Single Laboratory GC × GC Method Documentation
  - Method documentation – UD reports
    - UDRI Method FC-M-101(v2022) Hydrocarbon Type Analysis
    - UDRI Method FC-M-102 Polar Species Analysis
    - UDRI Method FC-M-106, Reverse Phase Thermal Modulation GCxGC for Hydrocarbon Type Analysis of Conventional and Alternative Aviation Fuels
  - Develop Reference Materials
  - Single Laboratory Precision
- Phase 2: Multi-Laboratory GC × GC Method Documentation
  - Multi-Laboratory Precision Validation
  - Identify Alternative Methods
  - Correlation Study

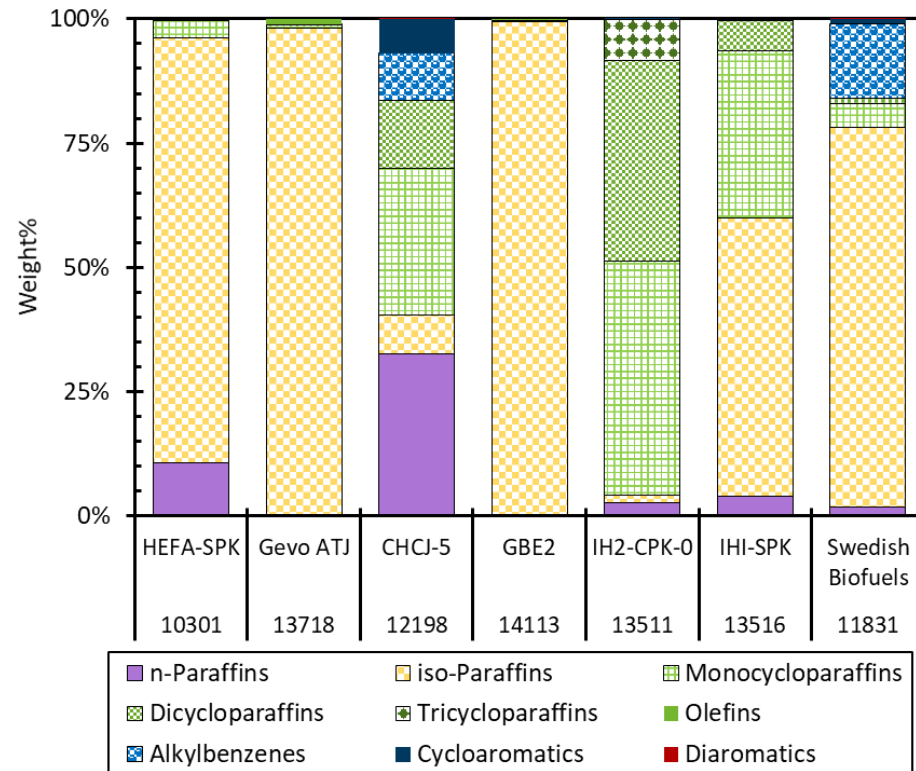
## Reference Materials



## Relative SD vs Mass%



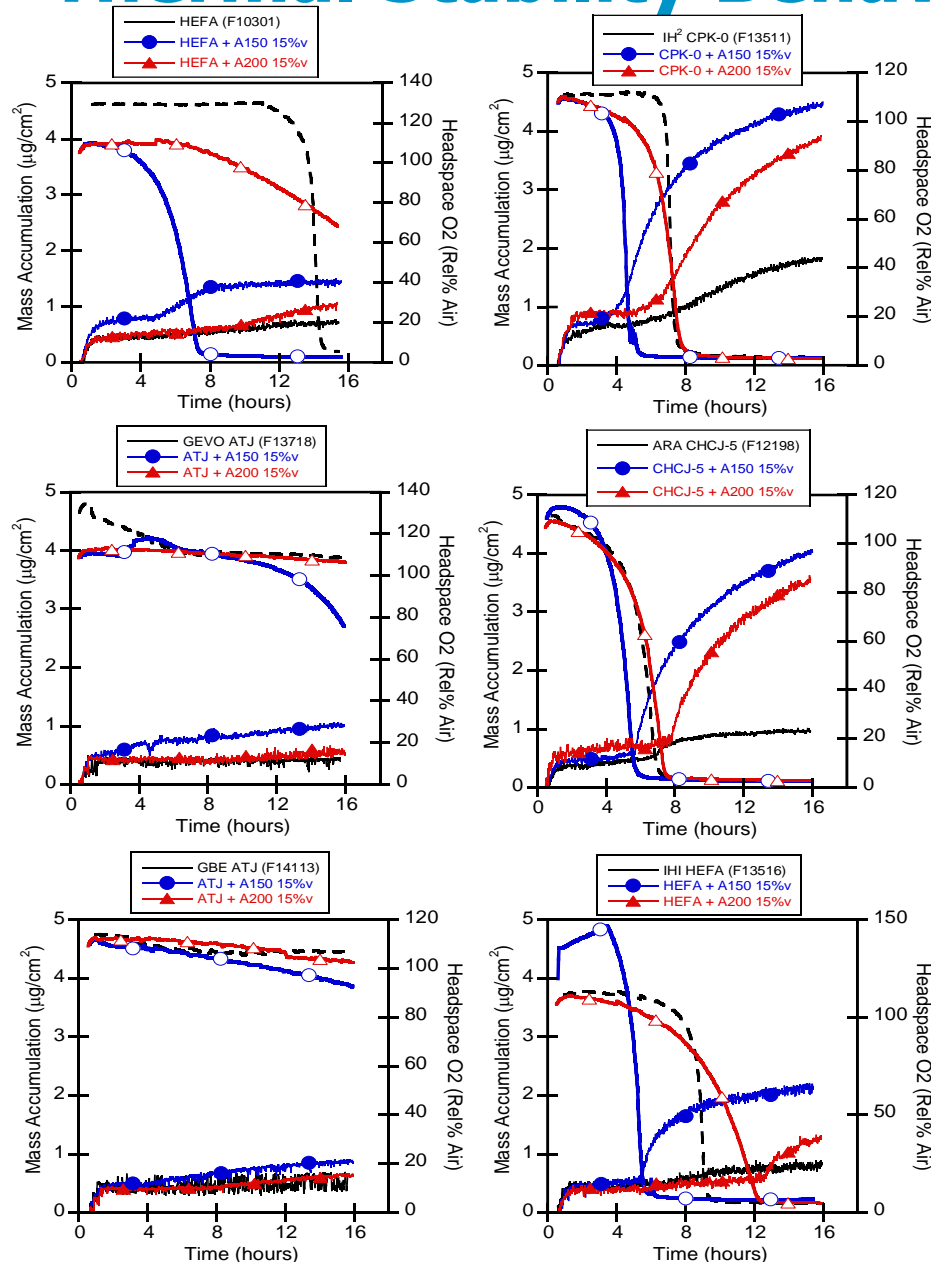
# Impacts of Aromatics on Thermal Stability Behavior



- Seven alternative fuels studied
- Aromatics added at 15%v
  - Exxsol A150 = alkylbenzene mixture
  - Exxsol A200 = diaromatic mixture
- Deposit and oxidation behavior measured in QCM apparatus (ASTM D7739)
- Results vary, general observations:
  - Moderate increases in deposition seen, but not for all fuels
  - Impact on deposition varies
    - Minor increases in deposition
    - Deposition usually A150 > A200
    - All fuels exhibit low to medium deposition even with aromatics
- Next step: JFTOT runs? Other aromatics?



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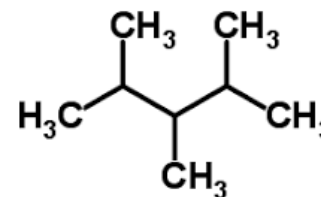


## Chinese Additives

- Chinese gov't has approached FAA/OEM committee for approval of SDA and CI/LI additives
- T1502 is similar to Stadis 450 – polysulfone, polyamine, sulfonic acid, in HC solvent @ 5 mg/L
- T1602 is similar to DCI-4a and other approved CI/LI additives – mixture of naphthenic acids @ 20 mg/L
- Property & materials compatibility testing has begun

## Renewable Iso-octane for Avgas

- Iso-octane has octane no. = 100



- Isobutene oligomerization --> Iso-octane
  - Gevo ATJ – fermentation produces isobutanol --> isobutene
  - Global Bioenergies – wood residues/sugars to isobutene
- Mixture of isomerized octanes
  - Determine composition & purity (~91%)
  - Measure important properties
  - Perform materials compatibility?

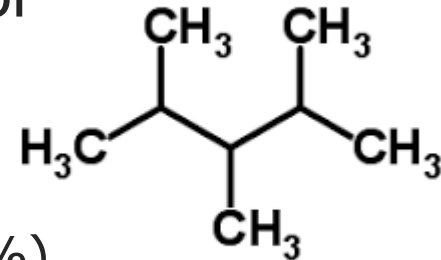
# Backup Slides



- Chinese gov't has approached FAA/OEM committee for approval of their SDA and CI/LI additives
- T1502 is similar to Stadis 450 – polysulfone, polyamine, a sulfonic acid, in a HC solvent @ 5 mg/L
- T1602 is similar to DCI-4a and other approved CI/LI additives – mixture of naphthenic acids @ 20 mg/L
- Use levels are also similar to ASTM D1655 approved additives
- Testing program just begun
  - Materials compatibility and key spec and FFP properties

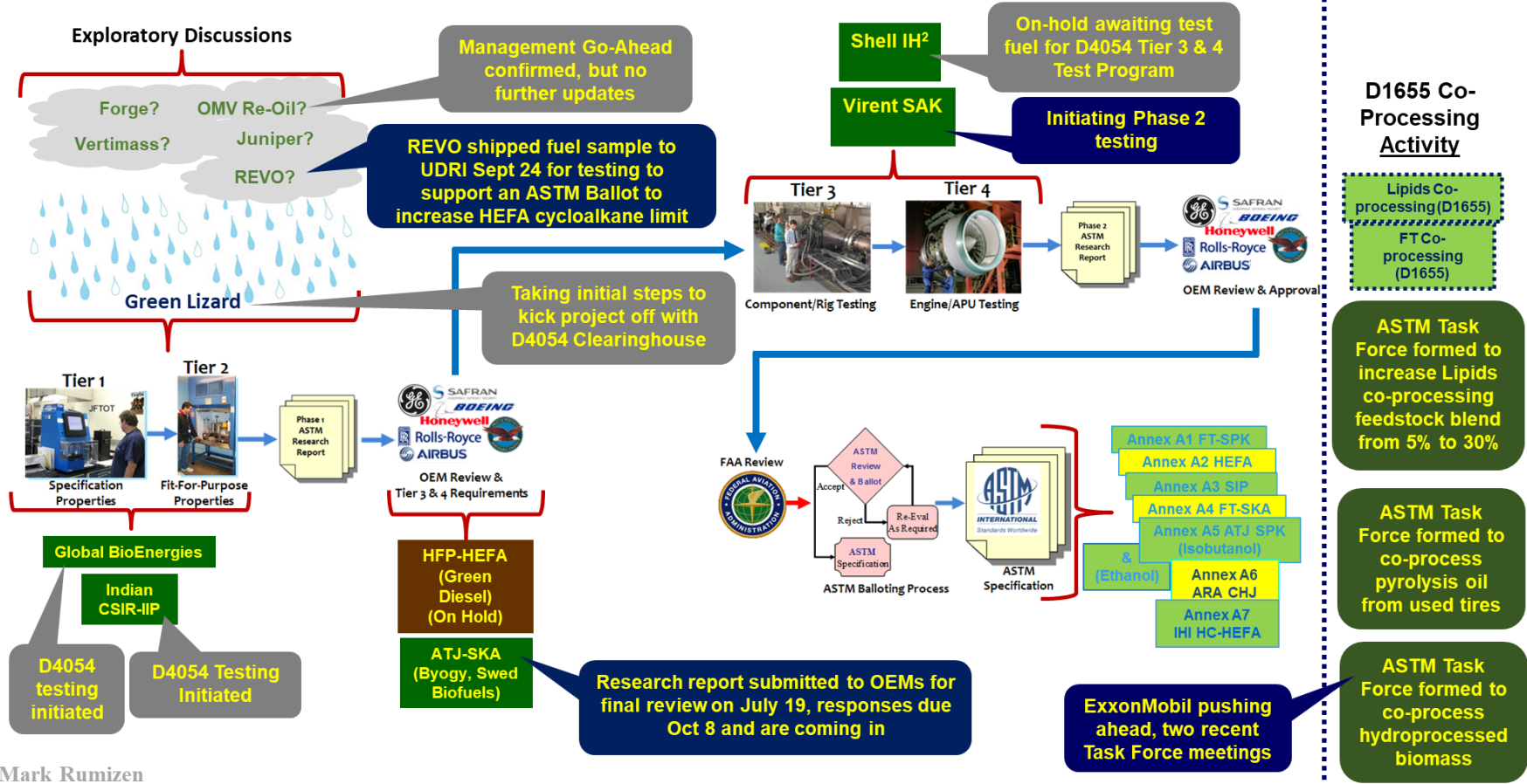
# Renewable Iso-octane for Avgas

- Isobutene oligomerization --> Iso-octane
  - Gevo ATJ – fermentation produces isobutanol --> isobutene
  - Global Bioenergies – wood residues/sugars to isobutene
- Both pathways are potential renewable source of Iso-octane for unleaded Avgas blending
- Result is a mixture of isomerized octanes
  - Need to determine typical composition & purity (~91%)
    - What are oxygenate impurities and their concentrations?
  - Need to determine & measure important properties
  - Need to perform materials compatibility?
- Two phase approach – neat iso-octane followed by blends with petroleum Avgas



# Candidate Fuels in Queue

## ASTM D4054 Alternative Jet Fuel Qualification Status

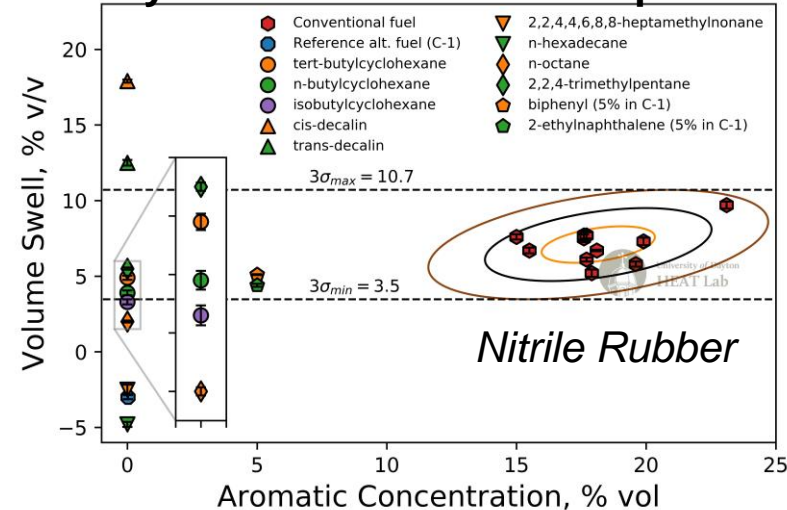


Mark Rumizen  
October 12, 2021

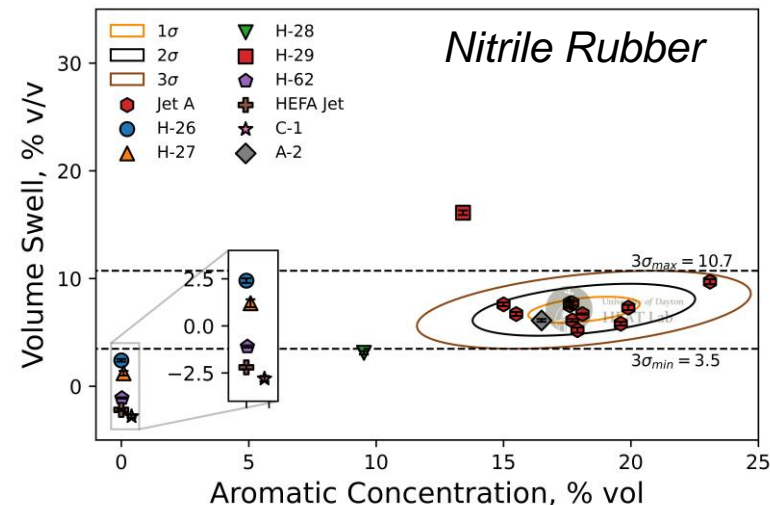
# Recent Seal Swell Work

- Several dozen samples tested:
  - Neat and blended samples
  - Several candidate SAFs
- Method to decrease test time have been explored
  - Test times are now halved
- Cycloalkanes can exhibit similar swelling behavior in nitrile rubber
  - structure is important; trans- and cis-decalin have approximately much variance as the 95%CI/ $2\sigma$  of conventional fuels tested.
- Non-linear blending behavior has also been observed.
- Next steps:
  - Additional tests with neat and blended molecules
  - Physical and numerical models
  - Comprehensive uncertainty quantification

## Cycloalkanes isomeric impact



## Candidate fuel results



- Alternative Fuel Candidate Evaluation
- Coordination of Research Report Review Process
  - Currently: Shell IH<sup>2</sup>, Global Bioenergies, Swedish Biofuels, CSIRP-IIP, Virent SAK, and ARA CHJ 100%
- FAA/OEM Review meetings moved to virtual
  - Now occur every 1 to 3 weeks rather than in person 3x/year
  - Includes OEMs not able to attend in person
  - More frequent virtual meetings have proven to be very beneficial
    - Likely to continue after in person meetings are restored
  - Next possible in person meetings:
    - CRC Alexandria May
    - ASTM D02 Seattle June



# New Clearinghouses – EU and UK



- Based on successes of FAA ASCENT Clearinghouse
  - Focus on UK/EU producers
  - Close coordination with USA Clearinghouse required
  - Support EU OEMs (e.g., Airbus & Safran) to complement ASCENT support
- EU Clearinghouse
  - EASA “Facilitation Initiative” recommends creation of EU clearinghouse based on US clearinghouse
- UK Clearinghouse
  - Initially funded at £3M for one year – 2021 launch?
  - Needs GCxGC to complete Tier 1/2 capabilities
  - University of Sheffield Sustainable Aviation Fuels Innovation Centre (SAF-IC) – not official Clearinghouse?