FAA Alternative Jet Fuels R&D Update

To: CLEEN Consortium Meeting

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Alternative Fuels Principles – U.S. Vision

• Alternative Jet Fuels must be drop in, have equivalent safety and better environmental performance than petroleum Jet fuel
• Enable all possible fuels that meet criteria
• Government role to address key barriers
• Work through Public-Private Partnerships
• Address the whole supply chain
• Leverage expertise and resources of other government agencies and other countries
• Aviation should be a lead user of alternative fuels
FAA Alternative Jet Fuel Activities

• **Testing**
  - Support Cert/Qual testing
  - Improve Cert/Qual process
  - Emissions measurements

• **Analysis**
  - Environmental sustainability
  - Techno-economic analysis
  - Future scenarios

• **Coordination**
  - Interagency
  - Public-Private
  - State & Regional
  - International
FAA Alternative Jet Fuel Activities

• Testing
  ▪ Support Cert/Qual testing
  ▪ Improve Cert/Qual process
  ▪ Emissions measurements
  ➢ Support evaluation of fuels for ASTM approval
  ➢ Reduce test cost and time for qualification

• Coordination
  ▪ Interagency
  ▪ Public-Private
  ▪ State & Regional
  ▪ International
Alternative Jet Fuel Pathways & Status

Resource
- Waste Gas
- Natural Gas
- Coal
- Solid Waste
- Lignocellulosic Biomass
- Sugar & Starch Crops
- Terrestrial Oil Crops & Waste FOG

Process
- Advanced thermo-processing
- Bio-processing
- gasification
- pyrolysis
- saccharification

Intermediate
- syngas
- alcohols
- bio-oil

Process
- F-T Synthesis
- Thermoprocessing
- Hydro-processing

Product
- Jet Fuel
- FT-SKA
- FT-SPK
- ATJ-SKA
- ATJ-SPK
- HDCJ
- SK, SAK
- SIP
- CH
- HEFA
- GREEN DIESEL

ASTM Status
- ASTM TF & Report
- Annex A1 Sept 2009
- ASTM TF
- Annex A2 July 2011
- Annex A3 June 2014

Draft – Subject to Revision – July 28, 2014
Fuel Qualification Support

Support ASTM Intl evaluation of alternative jet fuels

- Support ASTM D4054 testing activities to enable development of data for approvals
  - CLEEN
  - BAA
  - ASCENT Project 31

- Research Report Review
  - CLEEN

CLEEN has been instrumental
National Jet Fuels Combustion Program

Streamline ASTM International jet fuels approval process

• **Challenges to Alternative Fuel Approval Process**
  • Cost/duration of fuel approval process
  • Fuel quantities for rig/engine tests
  • OEMs uncertainty over effects of novel fuel composition and chemistry on combustor operability

• **Proposed Solution**
  • Develop generic fuel composition/chemistry evaluation methodology
    • Standardized rig/lab tests
    • Chemical kinetic/combustion modeling
  • Collaborative OEM/university/federal effort
ASCENT C/Q Projects (FY14)

- P25 NPCJF Area 1 - Chemical Kinetic Combustion
- P26 NPCJF Area 2 - Chemical Kinetic Modeling
- P27 NPCJF Area 3 - Advanced Combustion Test
- P28 NPCJF Area 4 - Combustion Modeling
- P29 NPCJF Area 5 - Atomization Testing
- P30 NPCJF Area 6 - Referee Swirl Stabilized Combustor Evaluation
- P31 Alternative Jet Fuel Test and Evaluation
- P34 NJFCP Area 7 - Overall Program Integration and Analysis
FAA Alternative Jet Fuel Activities

• Testing
  ▪ Support Cert/Qual testing
  ▪ Improve Cert/Qual process
  ▪ Emissions measurements

• Analysis
  ▪ Environmental sustainability
  ▪ Techno-economic analysis
  ▪ Future scenarios

➢ Improve understanding of environmental and economic sustainability of alternative jet fuel pathways
➢ Improve understanding of the potential availability of alternative jet fuels
**Alt Jet Fuel Emissions & Cost studies**

- **PARTNER Jet Fuel LCA Studies***
  - Focus on well-to-tank GHG and combustion CO₂
  - Emphasize influential aspects of fuel production on GHG emissions
  - Results are component of models and EPA analysis

- **Alternative Fuel PM emissions**
  - Coordinated with NASA, DOD

- **Alt Jet fuel cost estimation**
  - Multiple pathways
  - Identify opportunities for cost reduction
  - Coordinated with DOE studies


From DOE EERE Office of the Biomass Program
FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Lead Universities:
• Washington State University (WSU)*
• Massachusetts Institute of Technology (MIT)

Core Universities:
• Boston University (BU)
• Georgia Institute of Technology (Ga Tech)
• Missouri University of Science and Technology (MS&T)
• Oregon State University (OSU)*
• Pennsylvania State University (PSU)*
• Purdue University (PU)*
• Stanford University (SU)
• University of Dayton (UD)
• University of Hawaii (UH)*
• University of Illinois at Urbana-Champaign (UIUC)*
• University of North Carolina at Chapel Hill (UNC)
• University of Pennsylvania (UPenn)
• University of Tennessee (UT)*
• University of Washington (UW)*

* Denotes USDA NIFA AFRI-CAP Leads and Participants & Sun Grant Schools

ASCENT Website: http://ascent.aero
ASCENT P1 Alternative Jet Fuel Supply Chain Analysis

Objectives

• Develop information on regional supply chains for use in scenarios of future alternative jet fuel production

• Identify the key barriers in regional supply chains that must be overcome to produce 1 billion gallons of alternative jet fuel by 2018

• Support the Alternative Fuel Task Force (AFTF) of the International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP)
ASCENT Alternative Jet Fuel Supply Chain Analysis

Research Team

• **ASCENT Universities:**
  - Washington State (M. Wolcott)
  - Penn State (P. Smith)
  - U. Illinois (J. Endres)
  - U. Tennessee (T. Rials)
  - Penn State (T. Richard)
  - MIT (R. Malina)
  - Purdue (W. Tyner)

• **National Labs:**
  - Volpe, ANL (already onboard)
  - INL, NREL, ORNL, PNNL (as possible)

• **Cost share support:**
  - Biojet Canada (TC funded effort)
  - ITAKA (CLH Aviation, EC funded effort)
  - Delta Airlines
  - Byogy
  - Monsanto

• **Universities represented:**
  - Sun Grant Partnership
  - USDA AFRI Coordinated Agricultural Projects
    - Northwest Advanced Renewables Alliance (NARA via WSU)
    - Southeast Partnership for Integrated Biomass Supply Systems (IBSS via U. Tennessee)
    - Northeast Woody/Warm-season Biomass Consortium (NEWBio via PSU)
  - Bioenergy Science Center (via U. Illinois)

• **Kick-off Meeting – held in October:**
  - Team, CAAFI, Airlines 4 America, USDA, DOE, DLA-Energy, US Navy, and AFRL
ASCENT Alternative Jet Fuel Supply Chain Analysis

Project Layout

AJF Supply Chain Assessment

Feedstock Production
- UTK + Ullinois + WSU
  - Viable Feedstocks
  - Available Land
  - Growth and Yield
  - Cost of Production

Feedstock Logistics
- Volpe + INL
  - Distribution of Available Feedstock
  - Harvest and Preparation
  - Transportation Networks

Conversion Pathways
- WSU + Purdue + NREL + PNNL + MIT
  - Feedstock Requirements
  - Mass and Energy Balance
  - Intermediates and Co-Products
  - Infrastructure Requirements

Biorefinery Infrastructure
- WSU + Volpe + UTK
  - Regional Demand Centers
  - Petrochemical Refining and Distribution
  - Existing Assets for Retrofit

Biorefinery Value Chains
- PSU
  - Biorefinery Product Portfolios
  - New Product Development Strategies
  - AJF Market Adoption and Diffusion

ASSETS
- DOE Resource Assessment Inventory
  - POLYSYS
- Volpe Transportation Model
  - INL Biomass Logistics
- NREL Biofuels TEAs
- PNNL Biogeophysical Models
  - PNNL Geospatial Siting Tool

OUTPUTS
- Certification and Policy
- Stochastic Techno-Econ Analysis
- Supply Chain Analysis
  - Long Term (2050) Potential
  - MIT + ANL + Purdue

Risk Analysis

Ullinois
Purdue
PNNL + WSU + PSU
MIT + ANL + Purdue
ASCENT Analysis Projects (FY14)

- P1 Alternative Jet Fuel Supply Chain Analysis
- P13 ACCESS 2 Micro Physical Modeling with NASA
- P24 Emissions Data Analysis for CLEEN, ACCESS, and Other Recent Tests
- P32 Worldwide Life Cycle Analysis (LCA) of Greenhouse Gas (GHG) Emissions from Petroleum Jet Fuel
- P33 Alt jet fuel test data library
FAA Alternative Jet Fuel Activities

- Complement and leverage work of other U.S. agencies
- Complement and leverage work of private sector
- Support state/regional supply chain development and deployment
- Complement and leverage work of international partners

- Future scenarios

- **Coordination**
  - Interagency
  - Public-Private
  - State & Regional
  - International
U.S. Government Efforts Across the Supply Chain

- **Feedstock Production**
- **Feedstock Logistics**
- **Fuel Conversion**
- **Conversion Process Scale-up/Integration**
- **Fuel Testing / Approval**
  - Fuel Performance | Environment Assessment
- **Enable Production**
- **End User/Buyer**

Agriculture: Biomass Crop Assistance Program & Crop Insurance Program

Energy & Defense: R&D grants

Agriculture & Energy: R&D grants

FAA & Defense: C/Q Fuel testing

FAA, Defense, & NASA: Enviro Analysis

Agriculture, Navy, & Energy: Defense Production Act and Biorefinery Program

Defense & Airlines: fuel purchase

Agriculture: Feedstock Development Center Grants

Energy: R&D

Agriculture: Feedstock Development Center Grants

Energy & R&D

FAA: Guidance for Airports

EPA: Renewable Fuel Standard

FAA, Defense, & NASA: Enviro Analysis

Agriculture, Navy, & Energy: Defense Production Act and Biorefinery Program

Defense & Airlines: fuel purchase

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National Alternative Jet Fuels (AJF) R&D Strategy (in development)

Intended Purpose
Identify opportunities and strategically address challenges associated with Research, Development, Demonstration, and Deployment (RD3) along the development path of alternative jet fuels.

R&D Goals & Objectives
• Feedstock Development, Production, and Logistics
• Fuel Conversion and Scale-Up
• Fuel Testing and Evaluation
• Integrated Challenges

An undertaking by Aeronautical Science and Technology Subcommittee of the OSTP/NSTC with input from stakeholder community.

8 participating Departments & Agencies: USDA, DOC, DOD, NASA, FAA, DOE, EPA, NSF, DOS
Farm to Fly 2.0

… “THEREFORE, AS OUR GOAL, we the undersigned, jointly signify our intent to continue working together over the next five years in an expanded collaboration entitled “Farm to Fly 2.0”, to enable commercially viable, sustainable bio-Jet Fuel supply chains in the U.S. that are able to support the goal of one billion gallons of bio-Jet Fuel production capacity and use for the Aviation Enterprise by 2018”
CAAFI State & Regional Deployment

- Working with local lead organizations/POCs
- Provide context, advice, strategy, benchmarking
- Facilitate networks & links between stakeholders
- Link to Farm to Fly 2.0

"Farm to Fly" projects in process

- Commercial Execution Initiated
- "Farm to Fly" project dialogue

* Does not include Dept. of Energy Pilot Projects, Defense Production Act Projects, map credit to diymaps.net.
Coordinating with International Efforts

- Formal and informal coordination
- International Airshows
- Workplans - Bilateral Cooperation Agreements
- Coordination with R&D organizations
- Global Exchange meeting
- ICAO as forum for exchange
Alt Fuels Development Progress 2014

- ASTM approval of SIP fuels (June 2014), additional ballots under preparation
- Engine tests of novel fuels completed
- ASCENT analysis projects established
- Continued domestic and international engagement
Defense Production Act Update

- $510 million commitment by USDA, DOE and U.S. Navy
- In 2013 4 Phase 1 awards made to Emerald Biofuels; Nature’s Bioreserve; Fulcrum Bioenergy; Red Rock Biofuels
- In September 2014 Phase 2 awards made to Emerald Biofuels; Fulcrum Bioenergy and Red Rock Biofuels
- 100 million gallons of drop-in diesel and jet fuel to start production by 2016
- Cost competitive -- weighted average price in 2013 dollars <<$4/gal
Airline offtake agreements…announced thus far

- UNITED + AltAir Fuels = 5 M gpy from 2014
- Alaska Airlines + HAWAI’I BioEnergy = Supply in 2018
- Cathay Pacific + Fulcrum BIOENERGY = 370M usg
- BRITISH AIRWAYS + SOLENA GROUP = 180M usg over 11 years
- Southwest + RED ROCK BIOFUELS = 3 M gpy

3 December 2014
Alt Fuels Progress Anticipated in 2015

- Continue support to ASTM approval of additional fuel pathways
- Work to improve testing methods to reduce cost and time of Certification / Qualification over longer term
- Continue Analysis in support of deployment
- Continue domestic and international engagement
- CLEEN II
Summary

• Alternative jet fuels are a key component of FAA strategy in meeting environmental goals
• R&D efforts making progress on overcoming key challenges via testing, analysis and coordination
• Multiple programs and activities:
  – Commercial Aviation Alternative Fuels Initiative (CAAFI)
  – Continuous Lower Energy, Emissions and Noise (CLEEN) Program
  – Aviation Sustainability Center (ASCENT)
  – Farm to Fly 2.0
• Strong domestic and international coordination
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CLEEN 2 Alt fuels proposal areas

• A) Alternative Jet Fuel Test and Evaluation – Proposed Capabilities, To-Be-Determined Fuels
• B) Alternative Jet Fuel Test and Evaluation – Proposed Capabilities and Fuel(s)
• C) Alternative Fuels Analytical Method Development and Specification Research
• D) Support for the Alternative Jet Fuel Evaluation and Specification Development Process