Research and Development Investment Position Paper

May 8, 2013

From: Commercial Aviation Alternative Fuels Initiative (CAAFI®) Research and Development Team
To: Strategic Advisors and Funding Agencies Involved in Alternative Fuels

Dear Decision Maker:

Aviation is a critically important global industry, enabling the rapid movement of people and goods that is crucial to the current interconnected global economy. The U.S. economy depends greatly on an efficient and effective aviation system. However, the industry is acutely aware of the challenges posed by rising fuel prices, instability of fuel supplies, and environmental impact associated with emission of greenhouse gases and other pollutants.

Alternative, low-carbon jet fuels are anticipated to play a key role in meeting the aviation industry's energy independence and sustainability goals, including the international aviation industry's target of carbon neutral growth starting in 2020. Achieving sufficient levels of deployment to fulfill this potential role requires the well-considered exploration of all possible alternative fuel production methods, and the effective development and use of the diverse agricultural and inorganic resources that can form the basis for this production.

Last fall, over 80 members of the CAAFI R&D team, which includes a range of stakeholders from the aviation and alternative fuels industries, academia, and government, met to identify and discuss key immediate and longer-term needs for targeted funding to maximize the efficacy of the incipient alternative jet fuels industry:

Critical enablers requiring immediate development:

1) Flexible economic and engineering models capable of evaluating the wide variety of proposed approaches for alternative fuel facilities and supply chains
2) Detailed analyses of fuel chemistry effects on fuel properties to enhance specification development for alternative fuels with unusual chemical compositions (e.g.., those composed of a single or a few molecules), and development of cost effective tests for the suitability of an alternative fuel

R&D with near- and mid-term return on investment:

3) Feedstocks and processes to reduce the cost of hydrotreated esters and fatty acid (HEFA)
4) Studies on relative economics of competing uses of biomass resources.
5) Development and streamlining of crosscutting technologies applicable to a variety of feedstocks and processes

6) Feedstock production systems that incorporate diversity to enhance resilience to environmental variability and stresses such as drought.
7) Technologies to address barriers to the use of municipal solid waste and sewage sludge as feedstocks for alternative fuels.

Sustained R&D on high benefit, low readiness level processes:

8) Direct collection and conversion of atmospheric CO_2 to fuels

Additional details on each of these areas are as follows;

1) *Flexible economic and engineering models capable of evaluating proposed alternative fuel approaches*: Current economic and engineering models were developed with assumptions that do not match those for alternative fuels. Alternative fuel feedstocks vary widely in composition, may only be regionally and seasonally available, require evaluation of life-cycle costs and impacts, and so on. Models are required that can evaluate a variety of proposals, properly weigh the benefits of small-scale and distributed activities and collect and synergize the research knowledge base and make it available for analysis.

2) *Analyses of fuel chemistry impacts and cost effective tests for the suitability of an alternative fuel*: Current methods of qualifying aviation fuels involve specifications targeted at fuels derived from petroleum distillates and detailed, laborious testing of fuel suitability to ensure safety. However, we have almost no detailed understanding of how the actual chemical components of a fuel influence performance and safety, making it impossible to predict *a priori* what the potential issues are with a novel fuel, and full-scale testing is costly and requires tens to hundreds of thousands of gallons of fuel to complete. Approaches are being worked to make the specifications chemistry-based, to reduce the time and amount of fuel required for testing, and to be able to predict with confidence the impact of fuel type on operation and safety. These efforts need to be accelerated.

3) *Feedstocks and processes to reduce the cost of HEFA*: HEFA (hydroprocessed esters and fatty acids) are already qualified to be used as aviation fuel. The greatest challenge associated with this process is the cost of the final fuel, which is heavily affected by feedstock production costs. Current and proposed feedstocks can be developed to produce more oils with less land and cost, and higher crop yields. Downstream, conversion processes can be developed or modified to take advantage of lower quality oils, thus allowing use of a greater variety of oils. Investments in these areas yield immediate returns.

4) *Studies on relative economics of competing uses of biomass resources*: allocation of biomass resources to alternative jet fuels as opposed to other uses (e.g., power generation, other types of fuels, bio-based plastics, chemicals, etc.)

will be determined based on societal choices about priorities as well as relative economics of different uses of biomass. Understanding the relative economic performance of bio-based alternative jet fuels is critical to predicting their availability and success in the marketplace. Currently there is little information available about the relative economics and potential synergies among uses. Technoeconomic analyses addressing competition and synergies among biomass-based products can be performed immediately with existing techniques, but must be based on transparent, verifiable data and/or assumptions. Investment in these types of analyses enhance our understanding of whether technically viable pathways can also be economically viable. Rather than answering the question of how something can be done, these studies would answer the question of whether particular pathways should be pursued.

5) *Development of crosscutting technologies applicable to a variety of feedstocks and processes:* Perhaps the key challenge to alternative fuels is the diversity of feedstocks and processes required due to regional and seasonal availability. Yet some technologies can be common to many processes, such as collection, concentration, dewatering, small scale operation, and so on. Identifying and investing in these enabling technologies can bring significant benefits to the whole industry.

6) *Feedstock production systems that incorporate diversity to enhance resilience to environmental variability and stresses such as drought:* Diversification of crops, within field (concurrently or in rotation) and/or regionally can enhance the stability and reliability of feedstock supply, because some species will be more resilient to certain conditions than others, and therefore a mix is likely to be more stable than monoculture. Identifying suitable crop rotation schemes, species assemblages, and optimal regional diversity levels can aid in developing a robust supply chain for alternative fuel production in the face of increasing weather variability. Additional research is needed on diversification of algal cultures to address invasion by pathogens and predators leading to “pond crash,” or the collapse of the algal culture, which interrupts supply and causes costly cleaning and restart.

7) *Technologies to address barriers to the use of municipal solid waste and sewage sludge as feedstocks for alternative fuels:* municipal solid waste and sewage are waste products that are already being produced at massive scale. Currently, it costs money to dispose of or treat these wastes, but the use of wastes as feedstocks for alternative fuels may solve multiple problems of scale, cost, and waste disposal issues. Technologies are needed to facilitate separation, extraction efficiency, and conversion efficiency of such heterogeneous waste materials as feedstocks.

8) *Sustained R&D on low readiness technologies such as direct CO_2 conversion*: While facilitating progress of the current approaches, continued R&D should be

applied towards novel methods of CO_2 capture and conversion. Key tests and trials should be funded for promising ideas, prizes should be awarded to encourage innovation, research should be fostered in the universities and government laboratories, thus seeking the approaches with high pay-off potential.

The attachments provided with this letter give further details on a number of these key topics for R&D investment.

We, The CAAFI R&D chairs, appreciate your consideration of these topics at this critical time as the future of cost-effective, sustainable fuels is being explored and developed.

Sincerely,

The CAAFI R&D Trichairs for the CAAFI R&D Team
Michael Lakeman, Stephen Kramer, Mike Epstein