Before the United States House of Representatives
Committee on Science and Technology
Subcommittee on Space and Aeronautics

Hearing on
"Aviation and Emerging Biofuels"

Testimony of
Billy M. Glover
Managing Director of Environmental Strategy
Boeing Commercial Airplanes
March, 26, 2009

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Madam Chairwoman and Members of the Committee, thank you for the opportunity to offer The Boeing Company's views on sustainable biofuels for aviation.

As many of you know, The Boeing Company ("Boeing") designs and manufactures a range of commercial, military and space products. We are the largest aerospace company in the world, employing over 160,000 people.

Today The Boeing Company produces a family of 18 different commercial aircraft --- all quieter and more fuel efficient than earlier generations of aircraft. In fact, today's jet aircraft are 70 percent more fuel-efficient than jet aircraft produced only 50 years ago.

Despite the current global economic downturn, the demand for newer, more fuel efficient aircraft remains strong. In fact, we have almost 900 orders for our newest product, the 787 Dreamliner which should generate approximately a 20 percent reduction in fuel usage and emissions. We recognize, however, the aviation sector, as a key contributor to global GDP, must continually strive to improve its environmental performance to the extent possible and in line with industry growth. To be effective we must continue to make improvements on a global basis. [1]

Over the next 20 years, Boeing forecasts a demand for over 29,000 new large commercial aircraft worth approximately $3.2 trillion. We are concerned that demand for air travel and thus for commercial airplanes could be affected by future limits on CO2 emissions. We therefore are committed to looking for

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[1] Boeing is an active participant in the International Civil Aviation Organization (ICAO), the UN body that governs all aspects of international aviation. Through the ICAO Committee on Aviation Environmental Protection (CAEP) the industry has driven down aircraft specific emissions – CO_2, soot, and NOx -- on a global basis.

environmentally-friendly solutions and alternatives to the way air travel is conducted today.

We believe that sustainable biofuels for aviation have the potential to provide greatly reduced life-cycle greenhouse gas ("GHG") emissions and greater economic benefits associated with increased fuel availability.

When we use the term "sustainable biofuel" we mean a biofuel that, at a minimum, meets the following criteria:

1. Utilization of plants that do not compete with food, do not significantly impact biodiversity and do not jeopardize supplies of drinking water;

2. Total GHG emissions from plant growth, harvesting, processing and end-use are significantly lower than GHG emissions from fossil fuel extraction, production and end use;

3. In developing economies, development projects include provisions or outcomes that improve socioeconomic conditions for small-scale farmers who rely on agriculture to feed their families, and do not require the involuntary displacement of local populations; and

4. High conservation value areas and native eco-systems are not cleared for aviation plant source development.

We have identified four plant-derived oils that have very strong potential to meet our sustainability criteria: jatropha, camelina and halophytes in the near term, and algae in the longer term. Biofuels derived from these sustainable energy crop sources show significant improvements in terms of yield and environmental impacts when compared to traditional food crop sources currently being used to make ethanol and biodiesel fuels.[2] Overall, jatropha and camelina studies show GHG reductions of 60 percent or more, as compared to petroleum-derived jet fuel.

It should be made abundantly clear that Boeing has no interest in becoming a biofuel producer. Instead, we are using our expertise and reputation as an innovator to draw attention to the opportunities for a clean, renewable fuel

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[2] Preliminary well-to-wake life cycle assessments were carried out by Michigan Technological University for jatropha and camelina oil based SPK (see Appendix). A similar algal oil study is currently underway.

The basis for these studies is from recently available data on crop yields, oil content, and cultivation requirements1. Both camelina and jatropha show great promise for increased energy oil productivity without negatively impacting land and water use. The results of these studies indicate that more than 60-65 percent reduction in GHG emissions can be achieved by hydrotreated jet fuel relative to petroleum-derived jet fuel.

source in hopes of spurring and accelerating commercial development. In addition, we are using our technical capabilities to assure any new aviation biofuel meets all safety and performance requirements for our airplanes.

We are very confident that sustainable sources of plant-derived oils and processing methods can efficiently produce a high quality jet fuel. We have demonstrated that synthetic paraffinic kerosene ("SPK") made from plant oils can be blended up to 50 percent with normal jet fuel (Jet A or A-1) and operated in a commercial jetliner without any modification to the aircraft or engine.

When Boeing was asked to testify at this hearing, the Subcommittee posed a number of questions they would like us to address. Let me now turn to the Committee's questions.

Flight Demonstrations

Over the last year, Boeing has conducted four successful flight demonstrations with blends of biofuels. During each flight, a single engine was fueled by a mix of traditional Jet-A and biofuels.

- Virgin Atlantic Airways conducted the first test of a Boeing 747-400 with General Electric engines on February 25, 2008. That test flight operated between London Heathrow and Amsterdam with an 80/20 mixture of biofuel to kerosene.

- An Air New Zealand 747-400 equipped with Rolls-Royce engines was used to test a 50 percent biofuel blend in an engine ground run, and a test flight from Auckland, NZ on December 30, 2008. The flight lasted approximately 2 hours and consisted of climb, engine windmill restarts, as well as using starter-assists. Acceleration and deceleration checks were also carried out. A simulated approach-and-go-around was conducted at 10,000 ft.

- A Continental 737-800 with CFM engines was used to test a 50 percent jatropha and algae biofuel blend in an engine ground run, and an experimental flight from Houston, TX on Jan 7, 2009. The flight lasted approximately 2 hours, and consisted of a climb, engine accelerations and decelerations, a windmill engine restart, a starter assisted restart, and a simulated go-around maneuver at 10,000 ft.

- A JAL 747-300 with Pratt & Whitney engines was used to test a 50 percent biofuel blend in a ground run, and subsequent flight in Tokyo, Japan on Jan 30, 2009. The flight lasted approximately 2 hours, and consisted of a climb, engine accelerations and decelerations, and an engine windmill restart.

While we have not completed our evaluations from these test flights, some of the key lessons learned include the following:

- Lower freeze point -- In an initial comparison of biomass-based jet fuel and jet fuel from petroleum, we saw better freeze point performance from the biofuel blend. This is extremely important because aviation fuels must be able to perform in the very low temperatures experienced at high altitudes.

- Better energy density -- In several instances we observed better energy density in the fuel properties of the individual biofuels and in the biofuel blends when compared to traditional jet fuel. Higher energy density is an important benefit to aviation due to the unique lift needed to carry fuel for flight.

- No abnormal wear or engine deterioration -- Post-flight inspections of the aircraft and engines were conducted prior to the aircraft returning to service or entering into regularly scheduled maintenance. No abnormal wear or engine deterioration was observed.

We have no announced plans for additional flight demonstrations at this time. Our efforts are now focused on commercialization and certification of these fuels for aviation use.

Research, Development and Testing of Biofuels

Safety has always been, and will continue to be, the top priority of the Boeing Company. Safety is at the forefront of our efforts to develop and certify sustainable biofuels. Our most fundamental requirement for sustainable biofuels for aviation is also the most important requirement for their safest use -- sustainable biofuel must meet "drop in" requirements – *i.e.*, they must be able to be used in existing fuel delivery and supply systems and in existing aircraft without modification or special handling. And they must be fully compatible to be mixed with other approved fuels.

As discussed earlier, Boeing is developing a comprehensive report on the data collected from the recent flight and ground tests. We will be providing this report to the ASTM membership for further review and analysis. We are continuing to work closely with the ASTM[3] and other standards bodies in determining what additional research and/or testing may be necessary following completion of analysis and review of the results.[4]

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[3] The ASTM requirements in development will ensure that bio-derived fuels meet strict performance and compositional specifications to be compatible with existing petroleum-based fuels.

The three sustainable biofuels used for the flight and engine tests met all ASTM D 1655 performance specifications at a 50 percent blend with petroleum-based jet fuel.

Fuel property tests took place at several locations including Boeing, Honeywell UOP, Air Force Research Lab, several independent outside laboratories and the participating engine companies. Additional property and performance tests, including material compatibility, were conducted on these fuels at Boeing labs, the Air Force Research Labs and the University of Dayton Research Institute. Engine tests occurred at General Electric as well as Pratt & Whitney facilities.

Engine tests consisted of control, operability (engine start, flame-out and transient thrust characteristics) and performance, all of which tested within expected variation. No engine degradation was evident via control, operability and performance or hardware inspection at the conclusion of the test.

Operability testing included measuring start times, lean-blow out margin, acceleration and deceleration times. Emissions testing consisted of tests for the currently regulated emissions species; nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC), and smoke number.

Our testing revealed some surprising results, for example:

- The process to make the bio-derived SPK is feedstock agnostic;
- At a 50 percent blend ratio, a bio-derived SPK fuel performed equal to, and in some cases better than, traditional petroleum-based jet fuel in terms of performance and emissions;
- No change in aircraft systems, fueling infrastructure or engines is required for implementing bio-derived SPK fuels at up to a 50 percent ratio; and
- Large-scale production of a bio-derived SPK jet fuel is possible from sustainable sources

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[4] The ASTM process for specification of commercial aviation fuels supports the operational approval as administered by the FAA. It is a well established process. As a member of ASTM, Boeing is working closely with that body to establish a robust standard of certification for bio-derived fuels.

The Path Forward

We believe the principle challenges facing widespread use of biofuels in aviation are in the areas of commercialization, growth and supply of viable feedstocks, establishing standard lifecycle carbon and sustainability assessment methodologies and policies.

Right now biofuels, whether for aviation or other forms of transportation, are not being produced in sufficient quantities. This is due largely to the typical early challenges of commercializing an emerging technology, when development costs are highest and production processes have not yet reached economies of scale.

In addition, public policy investments and incentives often afforded existing technologies make it difficult for emerging technologies to be produced at competitive costs and offered at competitive prices. This is especially the case for emerging biofuels that must compete with decades of public and private infrastructure investments and extensive public policy incentives for fossil fuels. As a result, the sustained price of a barrel of oil needs to be at least $70 for biofuel producers to demonstrate competitive business cases that will generate the necessary investments in infrastructure (bio-refineries, equipment, etc.) and generate fuels that can be sold at prices competitive with existing fossil fuels.

Our current projections are that, with appropriate incentives, market viability could be achieved as early as 2015. Without such incentives, market viability will likely be delayed much later, possibly even a decade.

Boeing is convinced sustainable biofuels can significantly reduce aviation's carbon footprint. We are focusing our efforts on accelerating viable commercial markets for advanced biofuels from plant sources that do not compete with food crops and require minimal land and water use. We are committed to ensuring that our research and development investments in environmental improvements deliver significant greenhouse gas reductions.

While other forms of transportation have options to reduce their carbon footprint, for example by utilizing batteries and electric motors for propulsion systems, aviation must rely on three key strategies: continue to produce more fuel efficient aircraft; fly aircraft more efficiently by realizing the promise of Next Gen and improved air traffic management systems; and use low carbon sustainable biofuels.

Government can support the earliest commercialization and development of sustainable biofuels for aviation by:

- Creating incentives for sustainable energy crop growers and producers of sustainable biofuels for aviation;

- Ensuring public policy addressing greenhouse gas emissions does not discourage the development and production of sustainable biofuels for aviation.

- Creating predictable demand incentives for aviation use of sustainable biofuel blends, and assisting airlines to invest in new fuel supply chains;

- Implementing a refund of the aviation domestic fuel tax when sustainable biofuel blends are used; and

- Funding rapid development and implementation of reasonable, pragmatic, and standard methodologies for measuring total lifecycle carbon emissions and determining the sustainability of all liquid fuels.

Boeing is fully committed to working with fuel producers, airlines and the government to ensure the earliest development of commercially viable markets for low carbon sustainable biofuels for current and future aircraft generations.

Thank you again for the opportunity to testify today.

Appendix

Life Cycle Assessment of Green Jet From Plant Oils and Tallow: *Comparison to Petroleum Jet Fuel;* February 2, 2009; Dr. David Shonnard, Ph.D. - Professor and Robbins Chair in Sustainable Use of Materials, Kenneth Koers, M.S.- Department of Chemical Engineering and Sustainable Futures Institute; Michigan Technological University; Houghton, MI, USA; Copyright © David R. Shonnard, Kenneth P. Koers, Michigan Technological University, and UOP LLC

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4.3 GREENHOUSE GAS EMISSIONS

The emission of greenhouse gases (GHG) over the life cycle for each jet fuel alternative is shown in Figures 4 and 5. The GHG emissions include CO_2, CH_4, N_2O, and a large number of refrigerants and solvents having large global warming potentials. Only the first three gases make a large enough contribution to this analysis to be included in the figures. Figure 4 shows that only petroleum jet contributes GHG emissions during aircraft operation, and this portion to the petroleum jet GHG profile is the largest. About 15% of petroleum jet's GHG emissions occur during other stages of the life cyclce; prominently crude oil production and refining for fuel production. Biofuels such as green jet contain no fossil carbons in the fuel molecules, only carbon atoms sequestered from the atmosphere as CO_2 during plant growth. Therefore, these fuels do not contribute to climate warming when combustion occurs. The largest contribution to green jet GHG emissions occurs for plant cultivation for camelina and jatropha, followed by fuel production, plant oil production, and transportation. The largest contribution to the GHG profile for tallow GJ is from fuel production, since no impacts were included for tallow collection in this study. The GHG emissions for Camelina GJ show nearly a 62% savings compared to petroleum jet, and the GHG savings for jatropha GJ are nearly 65%, while for tallow GJ, savings are just over 90%.

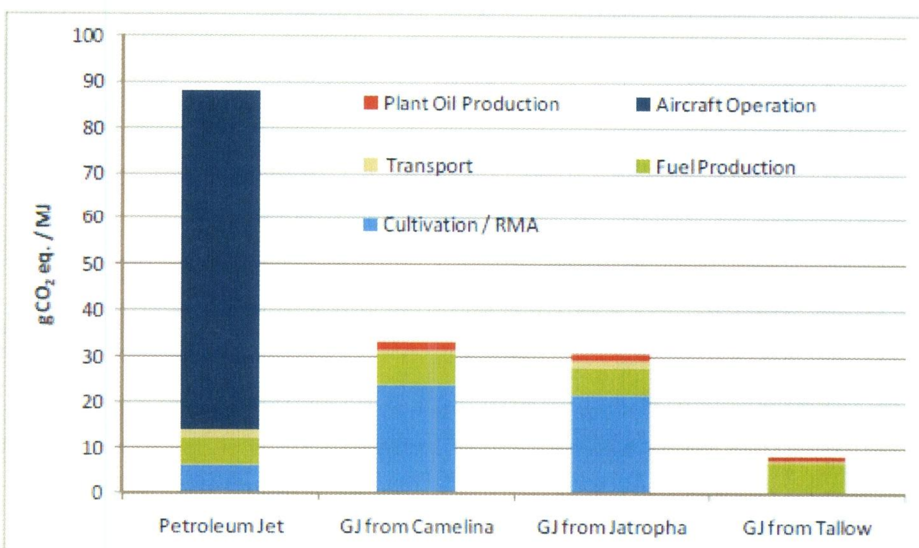

Figure 4: Greenhouse gas emissions for all fuels considered in this study

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