Discussion Topics

- Introduction
- Semi renewable jet fuel: Hydroprocessed renewable jet synthetic paraffinic kerosene (HRJ SPK)
- Fully renewable jet fuel: The Path to 100% Renewable Jet Fuel
Honeywell Corporate Overview

- 125,000 employees in more than 100 countries
- A Fortune 100 company – sales of $34.5 billion in 2008
- Global leader in advanced technology products, services and solutions

Honeywell
Technology Company, Financially Strong and Global
UOP Overview

• Leading supplier and licensor of processing technology, catalysts, adsorbents, process plants, and technical services to the petroleum refining, petrochemical, and gas processing industries for over 90 years

• UOP Technology Furnishes: 60% of the world’s gasoline; 70% of the world’s modern detergents; 60% of the world’s para-xylene

• ~3000 employees worldwide

• ’08 Financials: ~$2 billion sales;

• Strong relationships with leading refining and petrochemical customers worldwide

• 70+ processes in 6,000+ units in hydrocarbon processing industry; 300+ catalysts, adsorbents; 31 of 36 refining technologies in use today created by UOP

Track Record Of Technology Innovation
UOP Renewables Vision

- Building on UOP technology and expertise
- Produce **real** “drop-in” fuels instead of fuel additives/blends
- Leverage existing refining, transportation, energy, biomass handling infrastructure to lower capital costs, minimize value chain disruptions, and reduce investment risk.
- Focus on path toward second generation feedstocks & chemicals

**Oxygenated Biofuels**
- Ethanol
- Biodiesel

**Hydrocarbon Biofuels**
- Fuel & Power
  - Diesel
- Jet
- Gasoline

“Other” Oils: Camelina, Jatropha

First Generation
- Natural oils from vegetables and greases

Second Generation
- Lignocellulosic biomass, algal oils
Market Drivers/Enablers

- EU Emission Trading Scheme extending to aviation sector:
  - Aviation emissions: Fastest growing of any sector
  - 2012 Emissions: 97% of 2005
  - 2013 Emissions, 95% of 2005

- US Military’s National Security driven goals to achieve both greater substitution (~50% by 2020) & GHG reduction,

- Aviation industry OEM’s drive to render fleets compatible with upto 50% biojet

- Major Airline initiatives to use biojet

- Accelerated certification efforts

- 2nd gen feedstock initiatives:
  - Camelina, Jatropha, Algal
**Forecast of Industry CO₂ Emissions**

**Key Drivers of Emissions Reductions**

- Using Less Fuel
  - Efficient Airplanes
  - Operational Efficiency

- Changing the Fuel
  - Sustainable Biofuels

*Low carbon fuels a key part of emissions reduction*

*Presented to ICAO GIACC/3 February 2009 by Paul Steele on behalf of ACI, CANSO, IATA and ICCAIA*
UOP RE&C Technologies & Capabilities

Feed | Process | Product
--- | --- | ---
Natural Oil/Fats | Ecofining™ Process | Green Diesel
Hydrogen | | Green Jet (if req)
Natural Oil/Fats | Renewable Jet Process | Green Jet
Hydrogen | | Green Diesel

Envergent Technologies – UOP/Ensyn JV

Biomass | Rapid Thermal Processing (Pyrolysis) | Green Power / Fuel Oil (now)
--- | --- | ---
| | Upgrading Process | Green Fuels (2012)

Sustainable technologies – feedstock flexible & 2nd Gen ready

UOP Proprietary

HVO: ‘000’s barrels/day
Viable Sustainable Biofuel feedstock alternatives: Commercial Scale Production

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Readiness Time Frame</th>
<th>Challenges</th>
</tr>
</thead>
</table>
| Algae          | Ready in 8 to 10 years | - Technological innovation needed for processing  
                              - Algal Oil extraction key hurdle                                                          |
| Jatropha       | Ready in 2 to 4 years | - Limited to warm climates only  
                              - Mechanical harvesting isn't mature                                                        |
| Halophytes     | Ready in 5 to 7 years | - Proven at pilot scale  
                              - Improve agronomy for cost reduction                                                       |
| Camelina       | Ready Now             | - Limited total potential owing to yield  
                              - Somewhat tied to grain market swings                                                       |

Viability is based on timing, technology and local resources
Honeywell Green Jet Fuel™

- Started under DARPA contract to develop process technology to produce military jet fuel from renewable sources.
- Leverages Ecofining process technology.
- Fuel meets stringent requirements for flight.
- Military has ordered up to 600,000 gallons.
- Extend to commercial aviation in partnership with OEMs.

DARPA Project Partners

Demonstration Flights
UOP Stage Gate Process for Process Development: Green Jet Process Offered Commercially

- Idea Generation
- Scoping
- Concept Selection
- Development
- First Commercial Unit
- Product Launch

- Idea Screening
- Project Selection
- Dev’t Approval
- Scale-up Approval
- Product Launch Approval
- Post-Launch Review

- Passed Gate 4 in December 2009
- Ready For Process Design #1 in 1Q 2010

Enables UOP to guarantee new technology
Renewable Jet (Bio-SPK) Chemistry

**Feedstocks**
- Rapeseed
- Tallow
- Jatropha
- Soybean
- Algal Oils
- Palm Oil
- Camelina
- Greases

- Natural oils contain oxygen, have high molecular weight.
- First reaction removes oxygen – product is diesel range waxy paraffins
- Second reaction “cracks” diesel paraffins to smaller, highly branched molecules
- End product is same as molecules already present in aviation fuel
- End product is independent of starting oil

*Feedstock flexible, but with consistent product properties*
Synthetic Jet Fuels

Fischer-Tropsch (FT)
- Coal
- Natural Gas
- Biomass

Hydroprocessed Renewable Jet (HRJ) from Bio-Oils
- Plant/Algae Oils

Synthetic Jet Fuels
- Crude Oil
- Syn-Crude
- Bio-Crude

Conventional Refinery Processes

Hydroprocessing

Slide courtesy of Mark Rumizen, FAA/CAAIFI
UOP Renewable Jet Process

- Feedstock flexible
- Optimised for 50% SPK yield
- Makes valuable hydrocarbon co-products
  - Green Diesel
  - Green Naphtha
  - Green LPG
- Ability to swing anywhere between ‘Max SPK’ and ‘Max Green Diesel’ production to meet market demand

Commercial scale, proven technology
### Properties of SPK for Demo/Certification

<table>
<thead>
<tr>
<th>Description</th>
<th>Jet A-1 Specs</th>
<th>SPK (Jatropha)</th>
<th>SPK (Camelina)</th>
<th>SPK (Jatropha/Algae)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash Point, °C</td>
<td>Min 38</td>
<td>46.5</td>
<td>42.0</td>
<td>41.0</td>
</tr>
<tr>
<td>Freezing Point, °C</td>
<td>Max -47</td>
<td>-57.0</td>
<td>-63.5</td>
<td>-54.5</td>
</tr>
<tr>
<td>JFTOT@300°C Filter dP, mmHg</td>
<td>max 25</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Tube Deposit Less Than</td>
<td>&lt; 3</td>
<td>1.0</td>
<td>&lt;1</td>
<td>1.0</td>
</tr>
<tr>
<td>Net heat of combustion, MJ/kg</td>
<td>min 42.8</td>
<td>44.3</td>
<td>44.0</td>
<td>44.2</td>
</tr>
<tr>
<td>Viscosity, -20 deg C, mm²/sec</td>
<td>max 8.0</td>
<td>3.66</td>
<td>3.33</td>
<td>3.51</td>
</tr>
<tr>
<td>Sulfur, ppm</td>
<td>max 3000</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

- Over 20,000 US Gallons of Bio-SPK made for demonstration flights
- Certification supply work has uniquely allowed UOP to test the process and the catalyst at large Demo Capacity

**Fuel Samples from Different Sources Meet Key Properties**
Use of Green Jet Fuel: Semi-Synthetic Jet Fuel (SSJF)

- Green Jet Fuel can meet all the key properties of petroleum derived aviation fuel
  - Flash point
  - Freeze Point
  - Stability
  - Heat of Combustion
- SPK does not contain aromatics so must be blended with a source of aromatics, such as fossil jet fuel

A ‘drop-in’ biofuel for aviation
The Bio-SPK Program

- In 2008-2009, an industry team conducted testing of biofuel (Bio-SPK).
- The goal was to determine the feasibility of sustainable biofuels at blends up to 50%(v).

Certification-Qualification Phase
- ASTM D4054 Fuel Qualification Process

Slide courtesy of Mark Rumizen, FAA/CAAFI
**ASTM D7566 Issued 1st Sept 09**

**D1655**
5.1 Materials and Manufacture

**D7566**
Av Turbine Fuel Containing Syn HC’s

- **Annex 1**
  - Hydroprocessed SPK
    - Includes 50% FT Fuel

- **Annex for Each Class of Synthetic Blending Component**

- **Body of Spec Applies to Finished Semi-Synthetic Fuel**

- **Allow Re-Certification to D1655**

**Blend Comp’s Criteria and Blend % Limits**

**Table 1**
Blended Fuel Performance Properties

**Table 1**
Blended Fuel Performance Properties

Fuel Produced to D7566 Can Be Designated as D1655 Fuel

**Annex 2**
Other Adv Fuels or Processes

**Annex 3**
Other Adv Fuels or Processes

Certification of SPK to 50% targeted for early 2011

*Slide courtesy of Mark Rumizen, FAA/CAAFI*
Completed Flight Demonstrations

- **Successful ANZ Flight Demo** Date: Dec. 30, 2008
  Feedstock: Jatropha oil

- **Successful CAL Flight Demo** Date: Jan. 7, 2009
  Feedstock: Jatropha and algal oil

- **KLM European Test Flight**: November 23, 2009
  Feedstock: Camelina, Jatropha and algal oil
Military Testing

- Military demonstrations
  - Up to 600,000 gallons of fuel made from camelina, algae and animal fats for U.S. DESC
    - U.S. Air Force A-10 Thunderbolt II (camelina)
    - Navy F/A-18 Green Hornet (camelina)
  - Royal Netherlands Air Force Apache Helicopter (algae & used cooking oil)

Green Jet Fuel Meets Flight Specifications
US Military Supply Contracts

- US Military accelerating their biofuel certification program –
  - UOP is producing large volumes of jet fuel for an unprecedented HRJ-5/8 supply award from DESC

Contract awarded:

<table>
<thead>
<tr>
<th>Line item</th>
<th>Volume (gallons)</th>
<th>Type of Fuel</th>
<th>Feedstock</th>
<th>Prime</th>
<th>Producer</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40,000</td>
<td>Navy HRJ5</td>
<td>Camelina</td>
<td>Sustainable Oils</td>
<td>UOP</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>150,000</td>
<td>Navy HRJ5</td>
<td>Camelina</td>
<td>Sustainable Oils</td>
<td>UOP</td>
<td>Optional amount</td>
</tr>
<tr>
<td>3</td>
<td>100,000</td>
<td>AF HRJ8</td>
<td>Camelina</td>
<td>Sustainable Oils</td>
<td>UOP</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>100,000</td>
<td>AF HRJ8</td>
<td>Tallow</td>
<td>UOP (Cargill FS)</td>
<td>UOP</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>100,000</td>
<td>AF HRJ8</td>
<td>Camelina</td>
<td>Sustainable Oils</td>
<td>UOP</td>
<td>Optional amount</td>
</tr>
<tr>
<td>6</td>
<td>100,000</td>
<td>AF HRJ8</td>
<td>Tallow</td>
<td>UOP (Cargill FS)</td>
<td>UOP</td>
<td>Optional amount</td>
</tr>
<tr>
<td>7</td>
<td>1,500</td>
<td>Navy HRJ5</td>
<td>Algal oil</td>
<td>Solazyme</td>
<td>UOP</td>
<td></td>
</tr>
</tbody>
</table>

All from 2nd Generation Sustainable Feedstock
2nd Generation Renewable Jet Fuel: Fully Renewable Jet Fuel from Oils and Biomass

Natural Oils and Fats → Deoxygenation → Selective Cracking/Isomerization → Green Jet-range paraffins

Solid Biomass → Pyrolysis → Catalytic Stabilization/Deoxygenation → Jet Range cyclic hydrocarbons

Synthetic Paraffinic Kerosene

Renewable Jet Fuel

Renewable Jet Aromatics
The Future: 100% Renewable Jet

The Boeing hydroplane ran on 98% Bio-SPK and 2% renewable aromatics at SeaFair, Seattle in Aug 2009

<table>
<thead>
<tr>
<th></th>
<th>Jet A1 Spec</th>
<th>Starting SPK</th>
<th>Woody Pyrolysis Oil Aromatics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeze Point (°C)</td>
<td>-47</td>
<td>-63</td>
<td>-53</td>
</tr>
<tr>
<td>Flash Point (°C)</td>
<td>39</td>
<td>42</td>
<td>52</td>
</tr>
<tr>
<td>Density (g/mL)</td>
<td>0.775</td>
<td>0.753</td>
<td>0.863</td>
</tr>
</tbody>
</table>

Woody Pyrolysis oil aromatics produced through a UOP-NREL-PNNL CRADA
Summary

- UOP’s Renewable Jet Process was rapidly developed through key collaborations and by leveraging UOP’s world class hydroprocessing technology and expertise
- UOP’s Renewable Jet Process is ready to produce Bio-SPK in commercial quantities
- A multidisciplinary team succeeded in producing and testing sustainable SPK
- Certification of SPK to use in blends up to 50% is planned for early 2011.
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Preguntas?
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