Power and Energy Related Programs

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Energy Security Drivers

Influence from Global Suppliers

Price of oil bounces off four-year lows

OPEC president suggests large production cut on the way

Associated Press December 8, 2008 @ 1700

Oil prices rebounded from four-year lows and shot above $43 a barrel Monday as OPEC floated the possibility of a "severe" production cut and several countries announced new measures to boost their economies…

Russia wields the energy weapon

BBC News, Moscow, February 14, 2006

When Russia turned off the gas to Ukraine, it sent shivers across Europe where customers are increasingly dependent on Russia to keep warm.

Energy as a Strategic "Weapon"

Humanitarian Relief

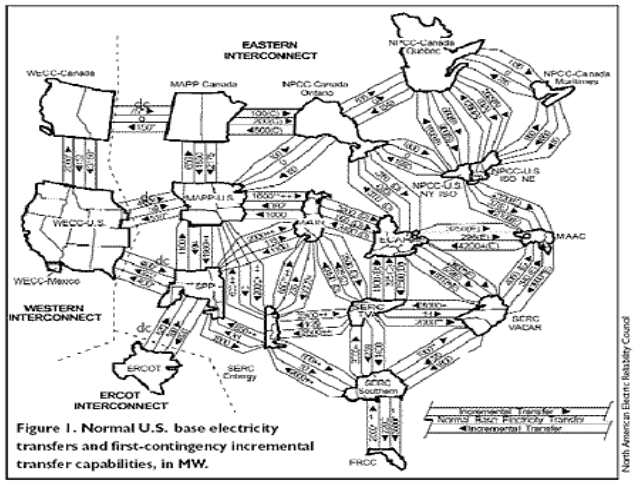
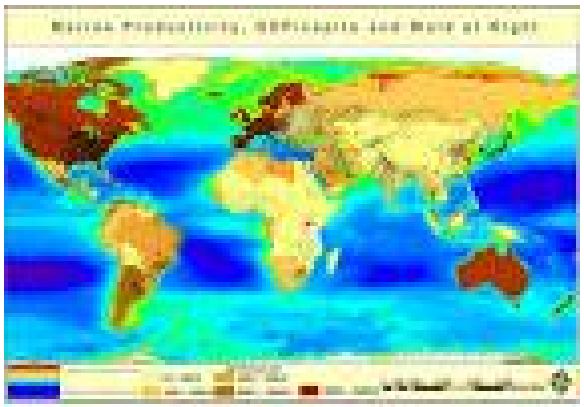


Figure 1. Normal U.S. base electricity transfers and first-contingency incremental transfer capabilities, in MW.

Grid Vulnerability

Future Systems



Climate Change????

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Military Need for Jet Fuel

JP5/JP8/JP8+100Usage

CY05: 54,113,000 Barrels

What we can do today

Petroleum Refining

Limitations
- Non renewable fossil feedstocks
- Dependent on foreign supplies

Ethanol Production

Limitations
- Energy Density less than JP-8
- Food-competitive feedstocks

Fischer - Tropsch

$$n\,CO + 2n\,H_2 \rightarrow -(CH_2)_n- + n\,H_2O$$

Limitations
- Not energy efficient
- Non-renewable fossil feedstocks
- No aromatics

Bio Diesel Production

Limitations
- Freeze point not suitable for aircraft

BioFuels Program

Objective: Produce a bio-derived JP-8 to reduce DoD dependence on petroleum-based fuels

March 2007 - October 2008

Highly-efficient conversion process to JP-8 from long and target chain oils

"Build-down" process:
- cracking/isomerization of C12-C16 to JP-8
- no crack process targeting C8-C16

Approach:
- Identify a broad variety of feedstock crops for oil extraction and processing to JP-8
- Develop multiple oil-to-JP-8 conversion pathways that are not specific to the origin or structural properties of the oil
- Submit a final bio-derived JP-8 sample for government testing and evaluation
- Diversify portfolio of agricultural / aquacultural source feedstock to avoid competition with current food crops

Proof of Concept: September 2007 – January 09
Demonstration: February 2009 – February 2011

Highly-efficient conversion process to JP-8 from short chain biomass waste

"Build-up" process:
- oligomerization of C2-C6 to JP-8

Algal Oil: December 2008 – June 2010
Celluose: March 2009 (est) – September 2010

Highly-efficient system for cellulosic feedstocks and low-cost algal oil production and conversion to JP-8

Optimize cellulosic process and algae selection to process oils to JP-8

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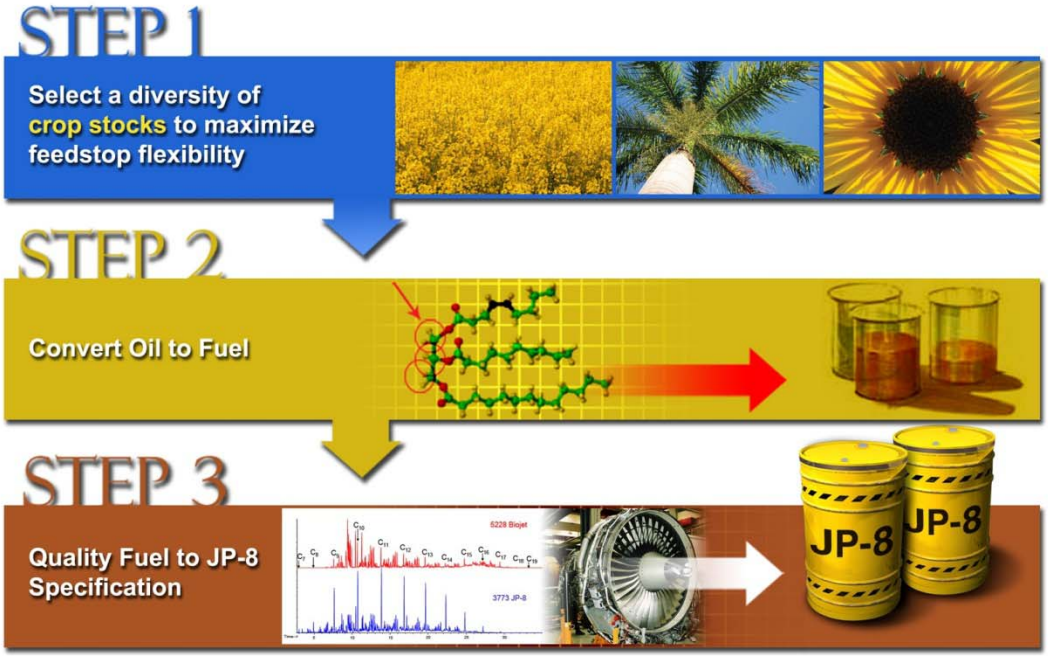
BioFuels



PROGRAM GOALS:

- Develop and demonstrate an affordable and highly efficient (60 – 90%) alternative process of converting crop oil to a bio-derived JP-8
- Diversify portfolio of agricultural feedstocks to avoid competition with current crop oil / food markets

Feedstock Flexibility
(Example Oils)

C_{22}-rich oils

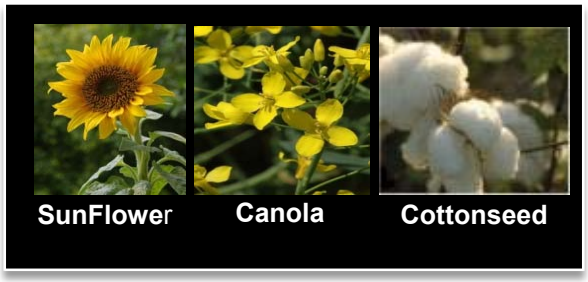
(Mustard family)
- High erucic rapeseed
- Pennycress

C_{16}-C_{18} fatty acid chains
- Palm fruit
- Camelina
- Algal
- Jatropha
- Tallow
- Tall oil
- Yellow grease
- Soy

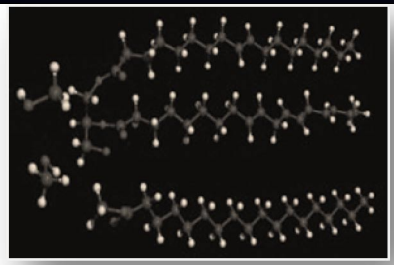
C_{10}-C_{14} fatty acid chains
- Coconut
- Palm Kernel
- Cuphea
- Babassu

BioFuels Program Objective

- **Develop an agro-synthetic path to cost effective JP-8**
  - Decrease reliance on petroleum-based fuels
  - Cap fuel cost growth
  - Leverage key U.S . strategic capability
- **Maximize oil/hectare yield**
  - Design to local field and weather conditions
  - Harvest from currently unused land / crop cycles
  - Renewable fuel source
- **Maximize JP-8/crop oil yield**
  - Catalytic / enzymatic transesterification

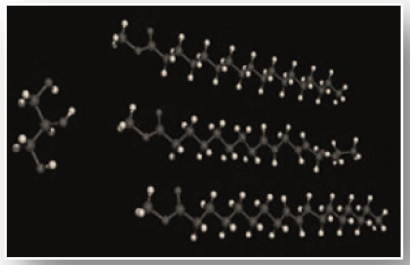


Extraction

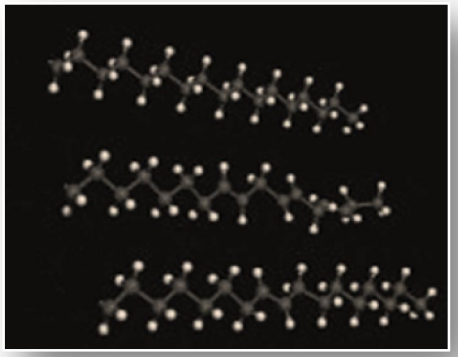


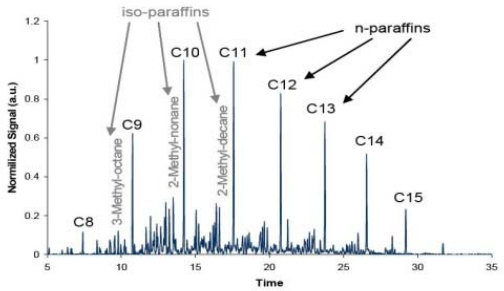
Triglycerides

Transesterification



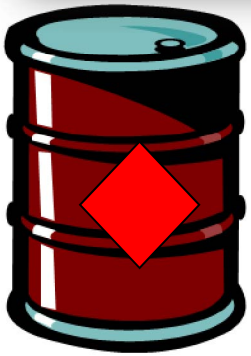
Crack and Clean



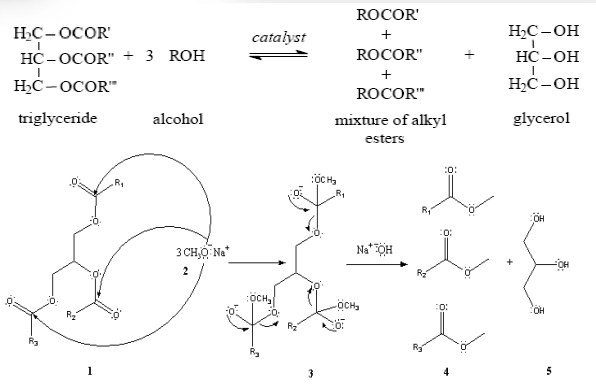


Retention Time in column

Composition of JP-8 used today



JP8



Program success enables production of renewable bio-derived fuels for DoD

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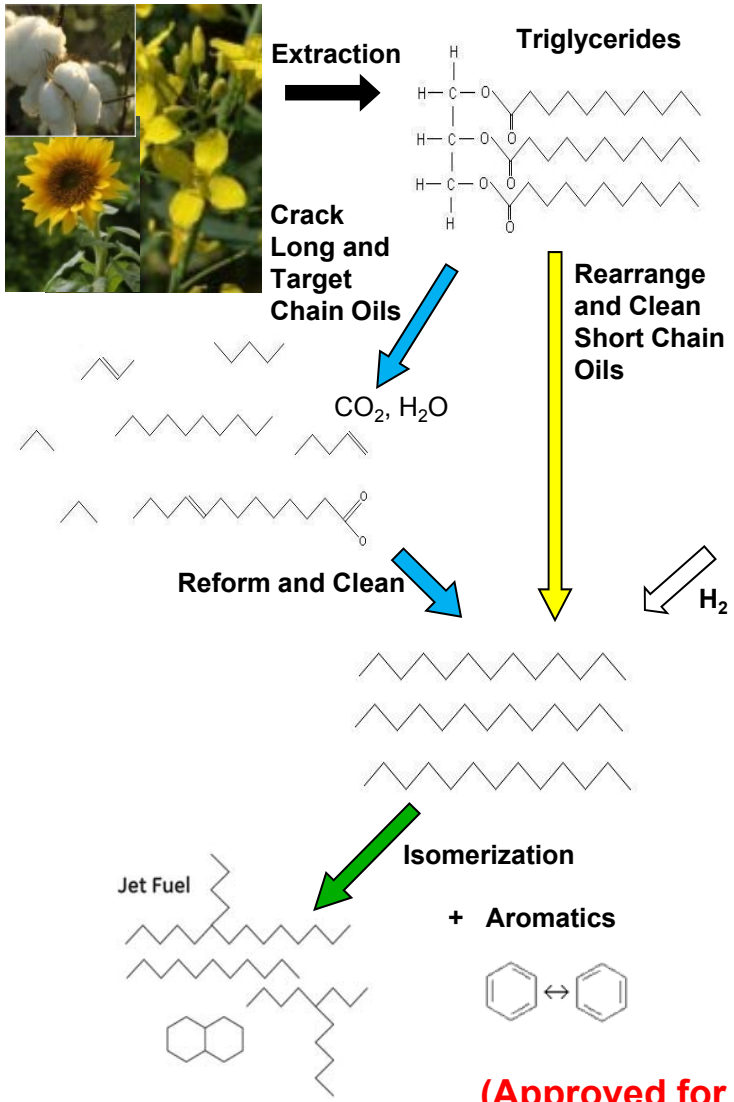
Conversion Process to JP-8 from Long and Target Chain Oils — Achievements

Designed, developed, and demonstrated a process with > 60% energy conversion of crop oil to jet fuel and identified development/ engineering opportunities to achieve 90% efficiency



Fuel Samples

- ✓ Bio derived fuel samples submitted to Fuels Branch / AFRL Wright-Patterson AFB
- ✓ All performers passed all first level critical specification tests for a JP-8 fuel
- ✓ Multiple pathways identified to JP-8 from crop oils

Final Deliverables

- ✓ Q1 FY09
- ✓ Final Fuel Sample – 100L of Bio-derived JP8
- ▪ Commercialization Plan
- ▪ Fuel Qualification Plan
- ▪ Analysis of development/engineering opportunities

Key JP-8 Developments

- ▪ **Oct 07:** Met Key First level specification testing (no aromatics)
- ▪ **Jan 08:** Met Key First level specification testing (including bio-derived aromatics)
- ▪ **Dec 08 – Present:**
  - ▪ Performer has conducted three independent flight tests to demonstrate blends of bio-derived jet fuel
  - ▪ Bio-derived fuel components created based on the foundation of the DARPA program technology

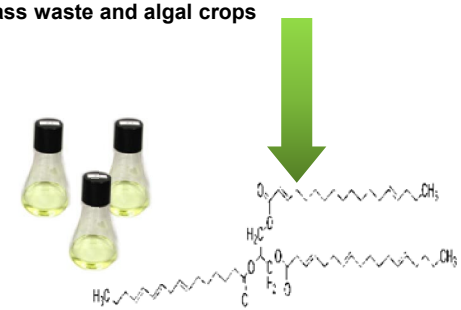
Cellulosic and Algal-Derived JP-8 Program Overview

Objective: An alternative and affordable feedstock

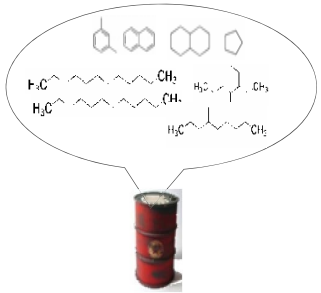
- **Algae: Key technical challenges**
  - Integrating advances in growth systems
  - Nutrition management
  - Cropstock selection
  - Waste stream management
  - Intermediate product extraction
- **Program Metrics**
  - Phase I
    - < $2/gal triglyceride oil from algae
    - Projected cost of production of JP-8 < $3/gal for a 50 Mgal/yr capacity
  - Phase II
    - < $1/gal triglyceride oil from algae
    - Projected cost of production of JP-8 < $3/gal for a 50 Mgal/yr capacity

- **Cellulosic: Key technical challenges**
  - Integrating methods for cellulosic biomass conversion
  - Biomass preprocessing
  - Hydrogenation
  - Oligomerization and isomerization of target biomolecules
- **Program Metrics (*contract pending*)**
  - Phase I
    - 30% efficiency, by energy, in the conversion of cellulosic material feedstock to JP-8
    - Projected cost of production of JP-8 < $3/gal for a 50 Mgal/yr capacity
  - Phase II
    - 50% efficiency, by energy, in the conversion of cellulosic material feedstock to JP-8
    - Projected cost of production of JP-8 < $3/gal for a 50 Mgal/yr capacity

Non-food biological feedstocks include triglyceride oils from biomass waste and algal crops



Triglyceride oils are cracked/ rearranged to meet desired carbon-chain lengths, and processed to JP-8



JP-8 for government testing and evaluation

Objectives of the DARPA Program

1. **Eliminate/reduce technical risk**
2. **Demonstrate scalability**
3. **Demonstrate commercialize-ability**
4. **Demonstrate qualify-ability**

Demonstrate Scalability

Phase II Deliverable: 4,000 L JP-8

Achieve cost objective at < 50 Mgal jet/year

Proportion of scale has to match the scale of agricultural activities

Mitigate business risk

Stabilize co-products

Understand potentially diverse types of Energy yields

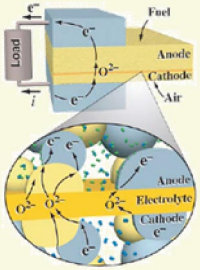
Final mitigation of business risk has to be driven by partners beyond DARPA

Surface Catalysis for Energy

Program Objective: Development of Surface Catalysts for High Efficiency in Energy Sources

I. JP-8 Fueled Fuel Cells:

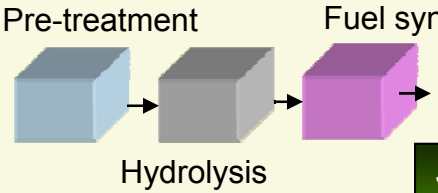
Develop catalysts for direct oxidation of JP-8 in Solid Oxide Fuel Cells for next generation fuel chemistries



Success enables one fuel logistics goals for portable power (JP-8)

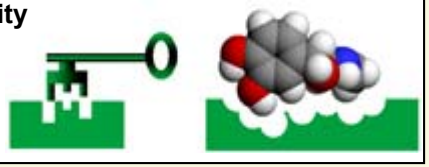
II. Biomass Fuels:

Use of surface catalysts for breakdown biomass into JP-8



Success enables efficient breakdown of biomass for liquid fuels

Mimic enzyme 'Lock-and Key' mechanism for maximum selectivity



Chemically Induced Photosynthesis

III. Solar Fuels:

Use surface catalysts and sunlight to efficiently breakdown carbon dioxide and water and rebuild complex hydrocarbons

Success enables development of liquid fuels (JP-8 goal) from waste streams

ENERGY & POWER

An indefinitely sustainable energy for the soldier in the field

Rapid establishment of *energy-self-reliant* forward operating bases

***Energy-self-dependent* regions or bases**

Thank you