



**Ames Research Center**

*in Silicon Valley*



# **ALGAL BIOFUELS: A GREEN AVIATION SOLUTION**

**NASA Green Aviation Workshop  
April 26, 2009**



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## **AGENDA**

- ◆ **The Status of Aviation Biofuels Research Today**
- ◆ **NASA's Role: Develop Algal Biofuel As A Green Aviation Solution**
- ◆ **NASA Ames Partnership Activities**



## AVIATION FUEL: ENVIRONMENTAL & ENERGY SECURITY CONCERN



### Environmental Concern:

- Nearly 70% of aircraft emissions are CO<sub>2</sub> (FAA 2005)
- Nearly 30% of aircraft emissions are water vapor - a greenhouse effect (FAA 2005)
- **Global CO<sub>2</sub> emissions from Aviation > 1000 Mt CO<sub>2</sub>/yr by 2025** (IPCC 4<sup>th</sup> Assessment Report)
- **US Aviation CO<sub>2</sub> emissions - 300 Mt CO<sub>2</sub>/yr by 2025**
  - **US General and Commercial Aviation - 350 million bbl/yr** (Bureau of Transportation Statistics for 2006)
  - **US Military - 130 million bbl/yr jet fuel** (Energy Bulletin, 2/26/06)



### Energy Security Concern:

- Aviation fuel is dependent on foreign oil from **hostile nations**.
- **Recent prices swings** from \$147/bbl to \$37/bbl have dramatic impacts on the nation's economic health

*Continued US reliance on fossil fuels makes America vulnerable – with potentially devastating effects on the environment*



## FEDERAL AGENCIES WITH BIOFUELS INITIATIVES

### Key Organizations

### Relevant History/Capabilities



- Sandia,
- NREL
- USDA



- DOE has the charter for developing biofuels technology
- R&D activities include overall development of critical biofuels technology. **NASA Ames assisting DOE with algal biofuels technology roadmap.**
- Teams with USDA on Energy Crop Initiatives.
- **No R&D focus on aviation concerns.**



- AFRL
- DARPA

- DARPA Issued a BAA for 3-year, biofuel-based jet fuel development
- AFRL develops alternative fuels for military flight. A number of renewable fuel flight tests flown on B-1, B-52, & C-17



- Aviation Policy, Planning and Environment Office
- Hughes Technical Center
- Joint Planning and Development Office

- FAA holds the primary responsibility for aviation policy-making,
- **Commercial Aviation Alternative Fuels Initiative (CAAFI). NASA is participating in this initiative (GRC)**
- NASA Ames and the FAA have successfully partnered on air traffic management technology development and testing

***Biofuels Development For The Unique Needs of General and Commercial Aviation Is Not Addressed***



## INTERNATIONAL BIOFUELS ACTIVITIES

### EU Regulation of aircraft emissions through a cap-and-trade program have led to new biofuels activities abroad

- ◆ February, 2008 - Virgin Atlantic completed the first biofuels test flight of a commercial plane from London to Amsterdam. The flight used a 20% blend of coconut and babassu oil.
- ◆ May 2008 - Airbus, International Aero Engines, Jet Blue, and Honeywell-UOP have partnered to develop jet fuel from algal oils. KLM also announces a partnership to developed algal based jet fuel with AlgaeLink.
- ◆ January 2009 – Air New Zealand completes a biofuels flight over Auckland. The flight used a 50% blend of jatropa oil.
- ◆ Spring 2009 - European Clean Sky Joint Technology Initiative will launch a \$1.6 billion public-private partnership research program aimed at reducing environmental impact from air transport, validating advanced technologies thru full-scale demonstrations.

***US Technology Leadership and Demonstrations on Aviation Biofuels Absent Due to FAA Restrictions and No Coordinated Development Strategy. Much R&D Needed To Develop Sustainable Aviation Biofuels***



## THE BIOFUELS ROLE FOR NASA

### **ROLE: Biofuels for General and Commercial Aviation**

NASA can address these R&D needs here.

### **WHY NASA?**

- Successful technology development for this sector under the AGATE program
- Unique R&D Biofuels Capabilities

### **BENEFIT TO NASA:**

- With Biofuels, NASA has a fully integrated program Green Aeronautics Program
- Biofuels technology will be needed for life-support on long-term NASA missions

*Working In Concert With Industry And Other Federal Agencies, Sustainable Aviation Biofuels Can Be Developed Within A 10-Year Timeframe*



## NASA'S AGATE PROGRAM

### Advanced General Aviation Transport Experiments

#### AGATE PROGRAM MISSION (1994-2002):

- NASA-led consortium of 76 members with the FAA
- **Research and develop technology** to reduce technical, operational, and regulatory bottlenecks for small aviation

#### ACCOMPLISHMENTS:

- Lightweight, affordable jet engine design
- Multifunction display for navigation & power
- Stream-lined flight training curriculum
- Real-time weather data link technology
- Lightning strike protection

#### PROGRAM BENEFIT:

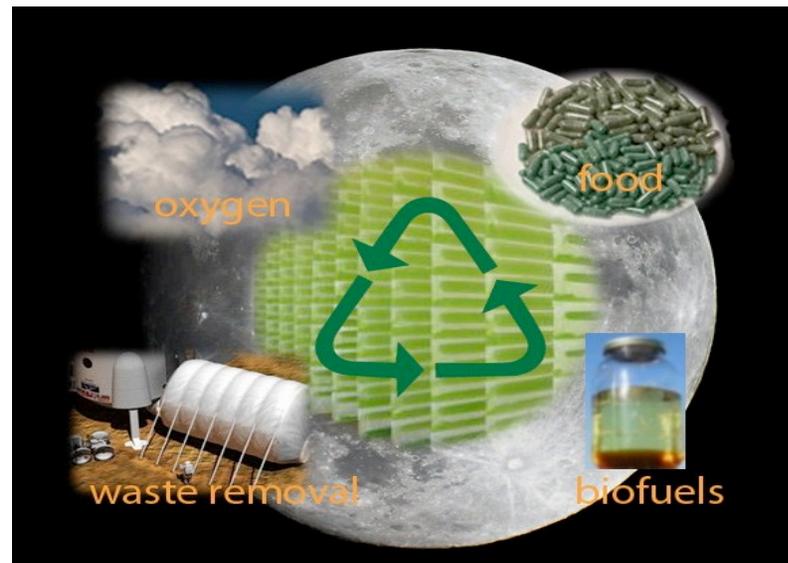
Using technologies from AGATE the small aviation industry rebounded from its decline ([http://jcac.jocogov.org/pdf/IXD\\_MasterPlan\\_ChapterTwo.pdf](http://jcac.jocogov.org/pdf/IXD_MasterPlan_ChapterTwo.pdf))

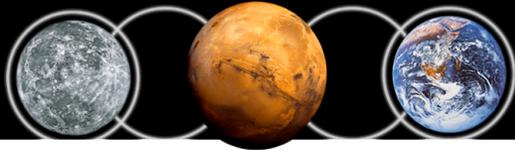


## IMPORTANCE OF ALGAL R&D TO NASA

### NASA APPLICATIONS:

- Air Revitalization:
  - CO<sub>2</sub>/Trace Contaminant Removal
  - O<sub>2</sub> Production
- Food Production: Human/Aquaculture Feed
- Water Treatment: Silica/Nutrient Removal
- Other Products: Biofuels, Hydrogen, Methane



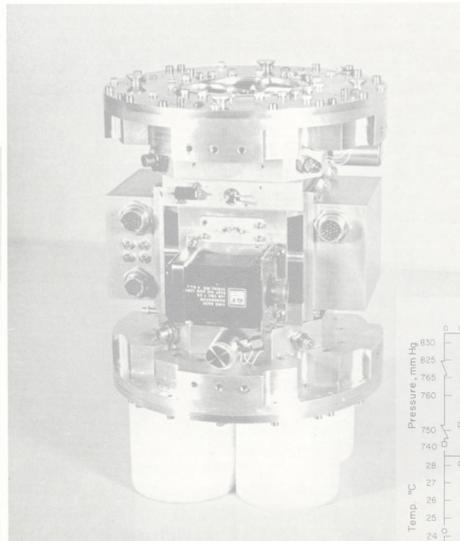


# HISTORIC NASA ALGAL SPACE RESEARCH

## Original NASA Algal Space Flight Experiments, 1960s:



Fig. 11. Experimental apparatus mounted in OVI satellite; note solar cell dome power system.  
C.H.Ward, S.S. Wilks, and H.L. Craft. 1970.  
Dev. Indust. Microbiol. 11:276-295



Source: Raymond Wheeler NASA KSC

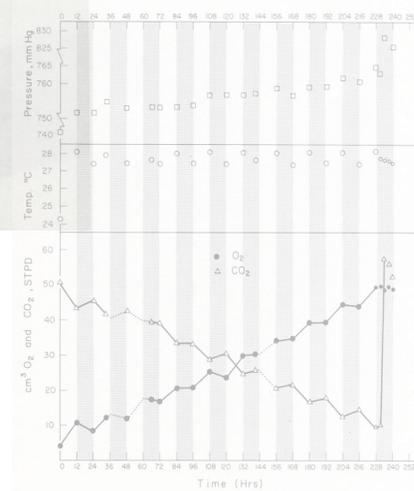


Fig. 19. Flight data: pressure, temperature, CO<sub>2</sub>, and O<sub>2</sub>.



## ALGAL RESEARCH TODAY AT NASA AMES

### Algae Growth:

- Photobioreactor research and development
- Algal biological contactor development
- Microsatellites with algae in space (Slime Sat)
- Extensive collection of algae from extreme environments

### Long-Term Manipulative Studies:

- Effects of algae communities on water composition, flow, irradiance

### Biofuels:

- Lipid extraction and analyses

### Environmental Control:

- Targeted carbon sequestration and nutrient removal (DOE collaboration)



ESA Photo: [ecls.esa.int/ecls/?p=biorat](http://ecls.esa.int/ecls/?p=biorat)



## ALGAL BIOFUEL R&D CAPABILITIES AT AMES

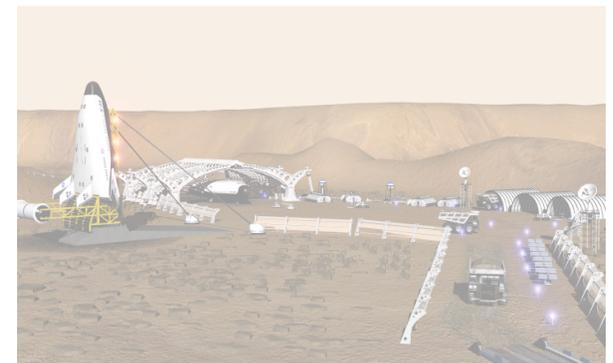
### Algae Growth:

- Characterization and Strain Selection:
  - Balancing lipid content, growth rates, and other properties
- Monitoring Algal Growth:
  - Algal ecosystems and growth needs
  - Monitoring capabilities for algal ecosystems
- Algae Manipulation



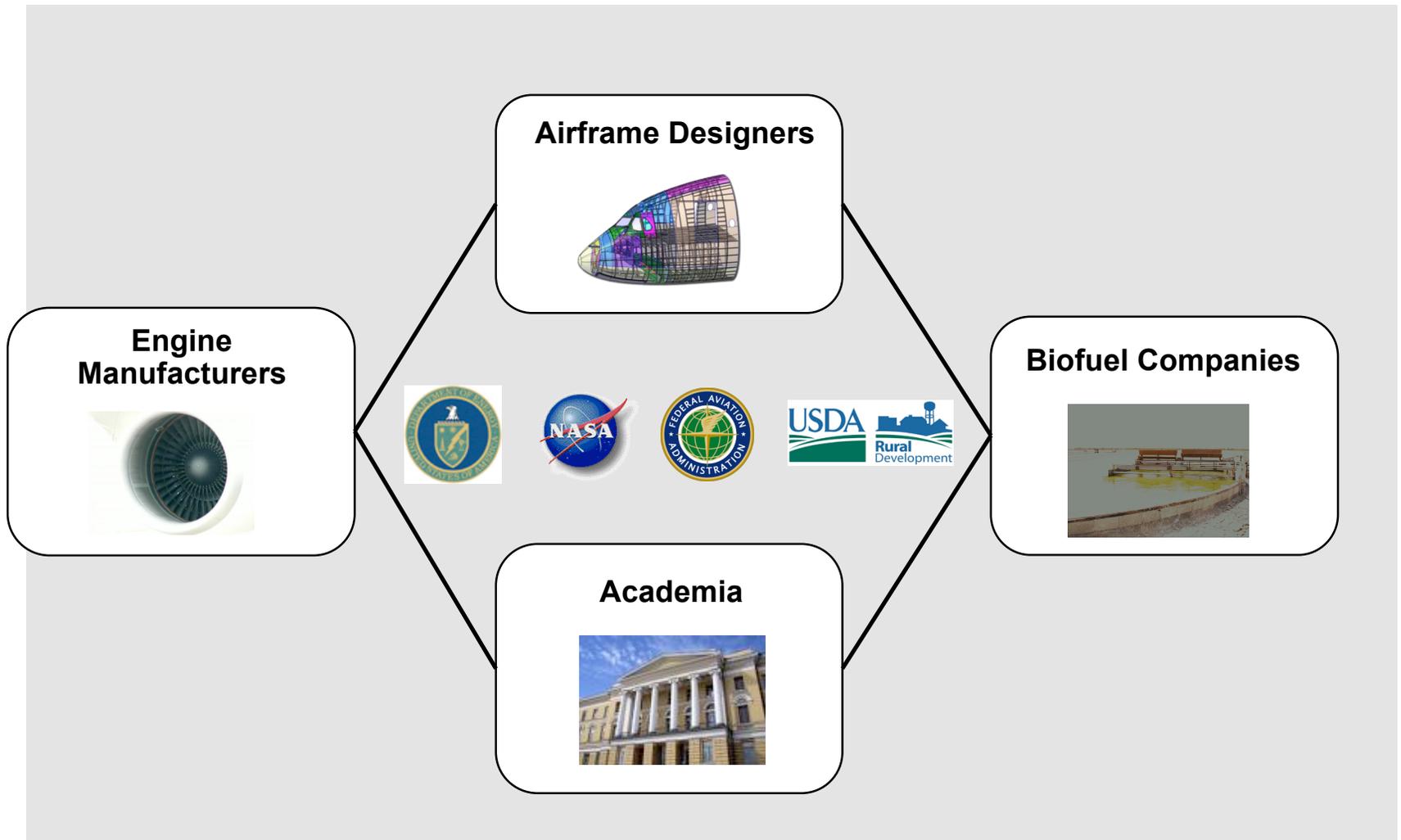
### System Engineering:

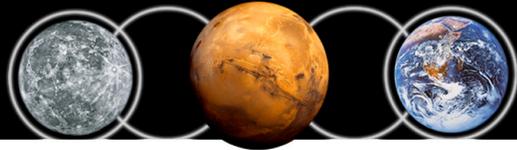
- Understanding of system requirements for complex systems
- Capability to technically facilitate and integrate algal processes into a single biorefinery system
- Ecosystem impacts; sustainability assessments





## PARTNERSHIPS ARE CRITICAL TO EFFECTIVELY DEVELOP AVIATION BIOFUELS



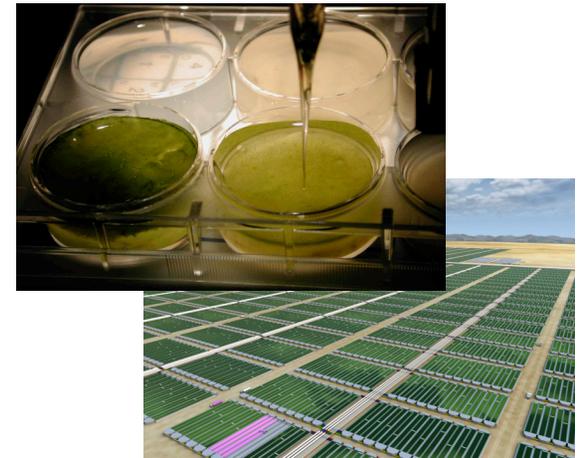


## ALGAL BIOFUELS CONSORTIUM (ABC)

# A National, Strategic Public/Private Partnership For The Development Of Algal Biofuels

### ABC includes:

- National Labs, Universities, and Industry
- Technologies, Expertise, and Facilities across:
  - Algal strain selection/growth
  - Algae harvesting and extraction
  - Biofuel refining
  - Co-product applications
  - System engineering



ABC does not represent DOE

**GOAL: To Leverage Partner Expertise To Help Define The Technology Roadmap And Provide Critical R&D To Commercialize Algal Biofuels**



## NASA AMES ALGAL BIOFUEL PARTNERSHIPS



### Currently Partnered With Industry and DOE

- Development of algal growth technologies
- Research algal ecosystems and manipulation studies



### Seeking Partners To Advance Algal R&D:

- The growth and manipulation of algal systems for aviation biofuels
- Develop algal growth technologies, including photobioreactors, ponds, and ocean-based systems
- Develop biorefinery systems leveraging NASA's algal and system engineering expertise

