General Atomics
Algae Biofuel Program

September 18, 2008

GENERAL ATOMICS

Goals of the Briefing

- **Introduce General Atomics**
- **Convey why we believe algae bio-oils might have an important role to play in providing an assured domestic supply of renewable fuel**
- **Create awareness of General Atomics' algae bio-oil programs**
- **Promote further collaboration**

GENERAL ATOMICS

LOCATION: San Diego, California

FOUNDED: 1955 by General Dynamics

STATUS: Privately held corporation

OWNERS: Neal and Linden Blue

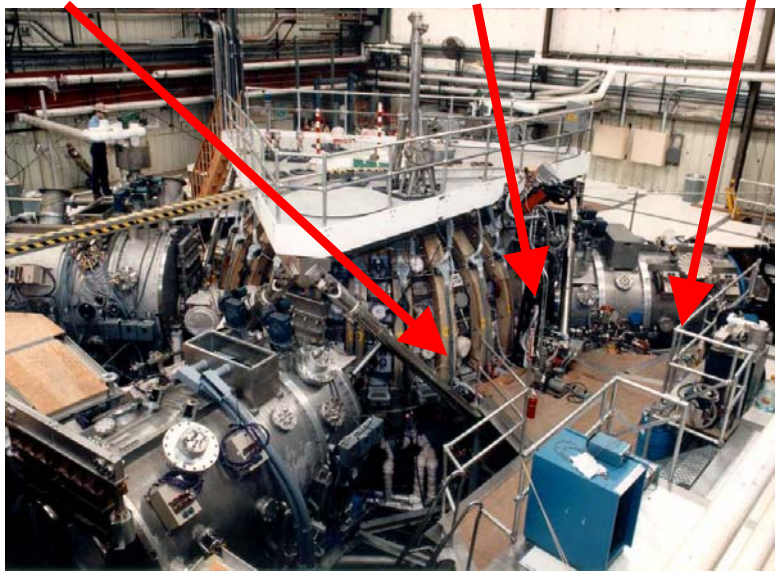
BUSINESS: High technology research, design, manufacturing, and production for industry and Government in the U.S. and overseas

DIII-D National Fusion Facility

MAGNETIC CONFINEMENT ACTIVELY CONTROLLED BY 500 MW POWER SUPPLIES

DIII-D TOKAMAK

NEUTRAL BEAM INJECTOR



DIII-D TOKAMAK

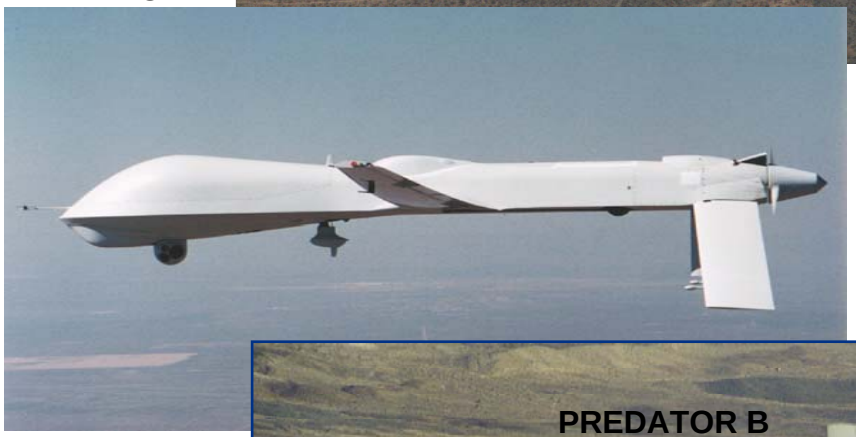
2 GJ – 575 MVA MOTOR GENERATOR

DIII-D Power yard

SURVEILLANCE & RECONNAISSANCE

I-GNAT

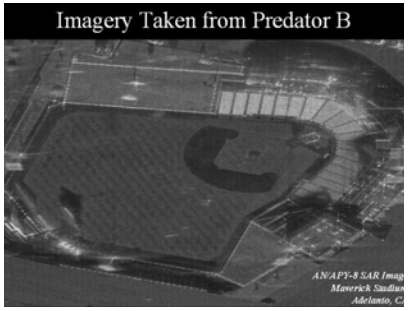
PREDATOR

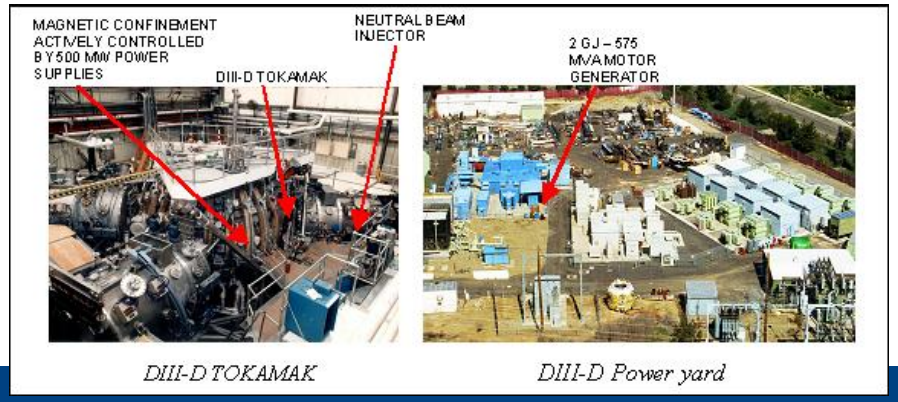


- Unmanned Air Vehicles
- Command and Control
- Defense
- Area Surveillance
- Scientific Research

STATE-OF-THE-ART
GROUND CONTROL STATION

GENERAL ATOMICS IS A DIVERSE HIGH TECHNOLOGY COMPANY





ALGAE BIOFUEL PROGRAM

Liquid Biofuels Have Attractive Characteristics

- Ethanol and Biodiesel Blends
- Technically Proven
- Good Political Base in the US
- Infrastructure Costs - Tolerable & Incremental
- Already in Use

Contribution is limited by Feedstock Availability

Ethanol and Biodiesel Feedstocks Must Be Expanded if They are to Contribute Substantially

- US transportation and diesel fuel requirements are 200 billion gallons/year
  - ~55% gasoline, 30% diesel, 15% jet fuel
- Reliance on food crops undesirable – and Limiting
- Cellulosic fuels could be part of the solution
- Biodiesel needs a non-food feedstock
- Algae Can Play that Role

Unique Potential of Algae Biodiesel – Near-term Energy Independence

- **Soybean Based Biodiesel will max out in ~3 years at a few percent of the possible US biodiesel fuel market**

- **15 million acres of algae would supply ALL US transportation fuel**
  - US currently uses 970 million acres for crops & grazing

Commercial Algae Farm

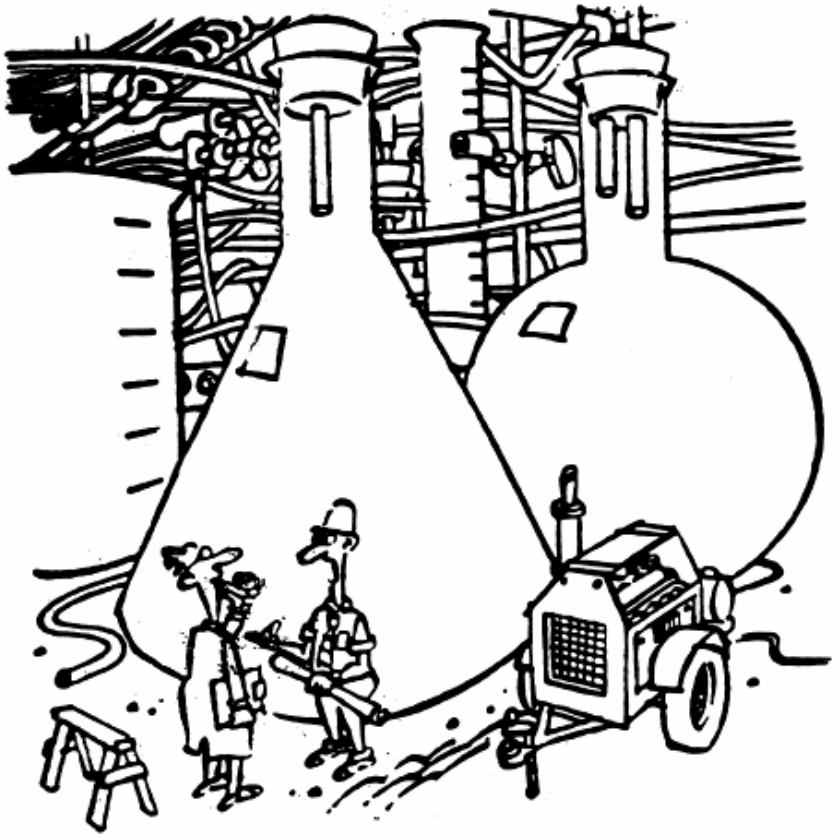
Crop	Gal/Acre Of Oil
Soybean	48
Peanuts	113
Rapeseed	124
Coconut	287
Palm Oil	635
Algae	5,000 – 15,000

Energy Independence and Reduced Environmental Impact - What's the rest of the story?

- **DOE algae biodiesel program (1980-1997)**
  - Demonstrated technical feasibility
  - Projected costs were very high
  - Large-scale demonstration derailed by contamination with local algae species

- **Clearly there are problems to be overcome. However …**

NREL APPROACH WAS BASED ON LABORATORY BIOLOGY, NOT BIOCHEMICAL PROCESSING



We seem to have a few problems going from lab-scale to full-scale production!

Concluded Genetic Engineering was the Only Solution

Current Cost Component Assessment

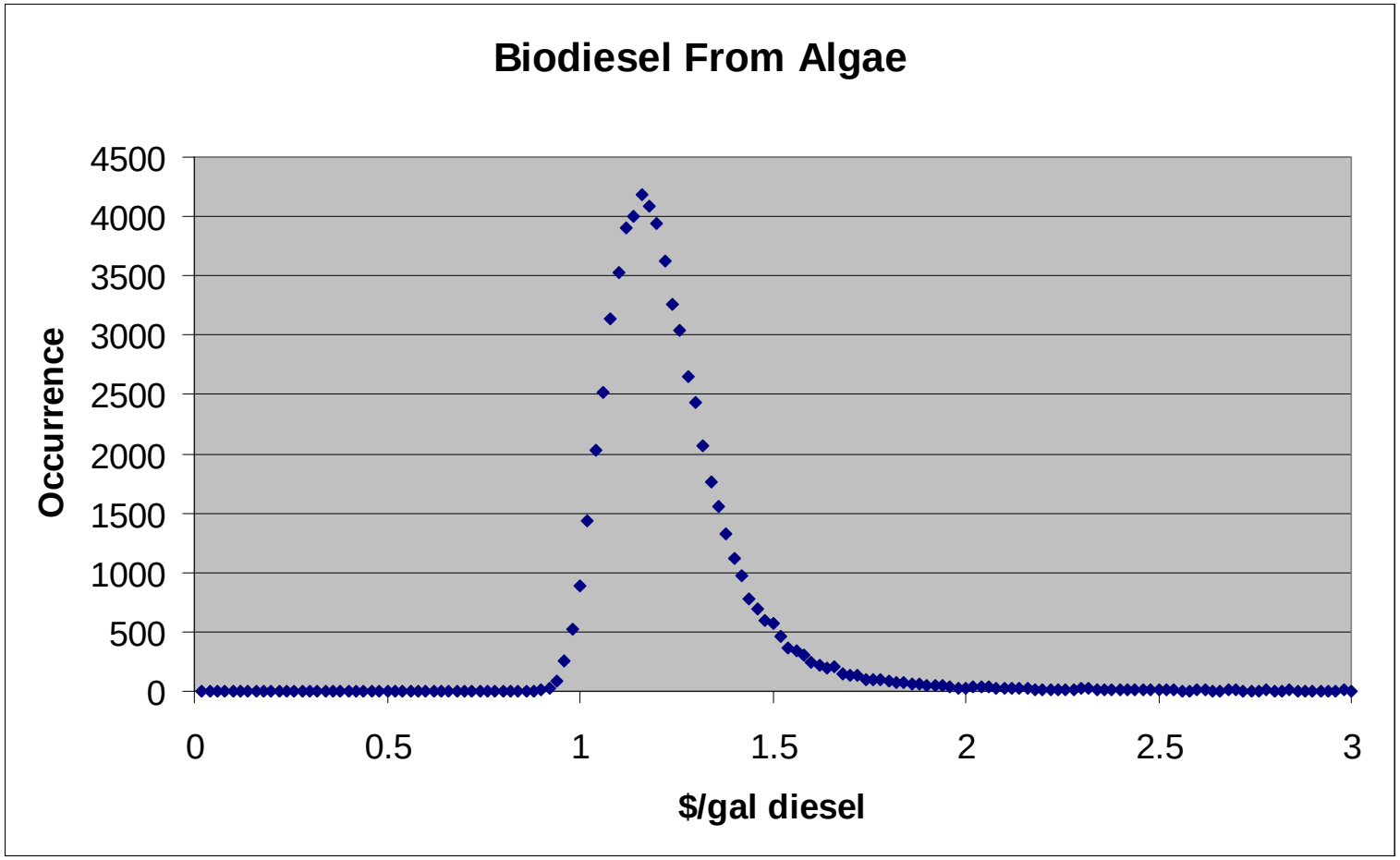
Cost Component	Conventional ($/gal)
Algae growth	$15.00 – $20.00
Water and nutrient supply	$0.40 – $0.70
Carbon dioxide supply	$1.20 – $2.40
Harvesting	$0.80 – $1.60
Oil extraction	$1.50 – $2.60
Inoculation	$1.10 – $5.50
Algae oil subtotal	**$20.00 – $32.80**

Algae Growth
Clearly Dominates
But
Every Component Must
be Reduced to Reach
$1/gal oil

Substantial Cost Reductions Appear Achievable

- **GA's patent pending process improvements are expected to significantly lower the cost of microalgae biodiesel**
  - **Growth efficiency**
  - **Cellular oil concentration**
  - **Nutrient utilization**
  - **Reactor design**
  - **CO_2 delivery**
  - **Separation technology**

Typical Cost Output from Monte Carlo Analysis



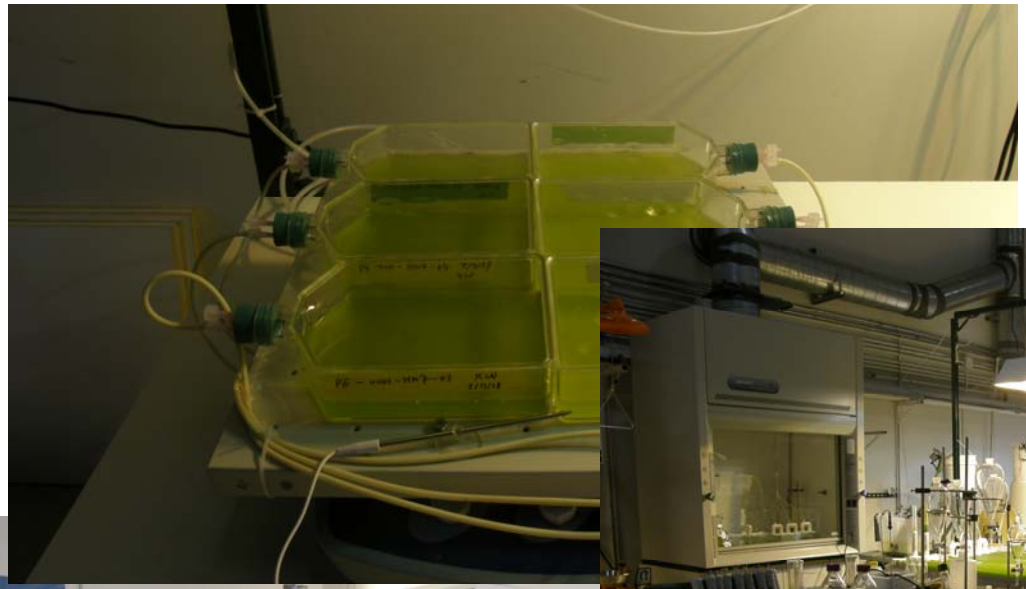
GENERAL ATOMICS

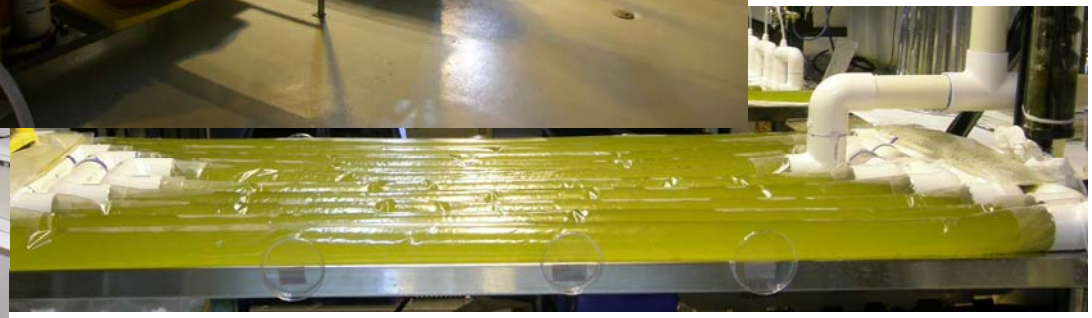
Three Phase Program to Prove Process Economics

4 years

- **Guided by Cost Sensitivities**
- **Phase I: Technology Development**
  - Algae growth
  - Process unit operations
  - Pilot plant design
- **Phase II: Pilot-Scale Testing**
  - Install algae growth ponds
  - Install pilot-scale harvesting and separation equipment
  - Conduct engineering-scale design data tests
- **Phase III: Demonstration Plant**
  - Build a 100 acre demonstration facility
  - Demonstrate technical performance and economic viability
  - Collect data for design of commercial facilities

BEGAN EXPERIMENTAL WORK IN 2007





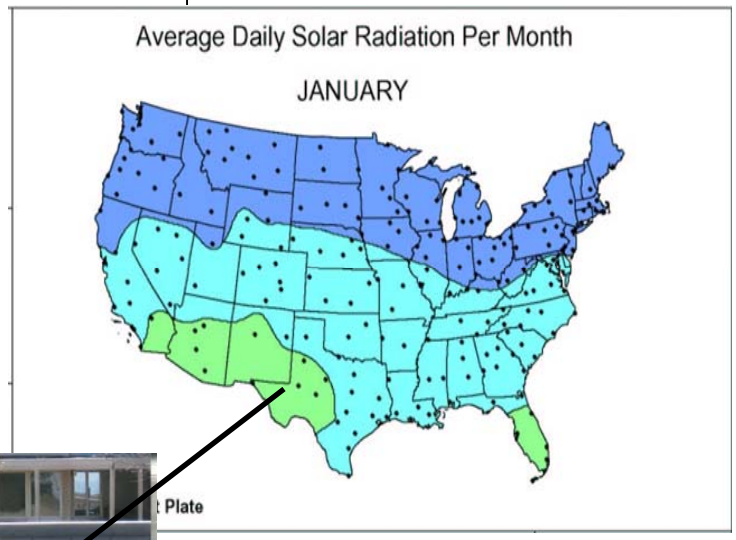
INITIAL OUTDOOR WORK IN SMALL RACEWAYS

2008 ADDED LARGER RACEWAY AND PONDS

So Testing to Assess the Needed Technical Advances is Currently On-going at GA ‘s Algae Facility

And the results to-date have been promising

STARTING UP SECOND FACILITY IN PECOS TEXAS



SUMMARY

- ALGAE BIOFUELS HAVE POTENTIAL TO PROVIDE INDEPENDENCE FROM OIL
- EMBARKED ON PROGRAM TO ACHIEVE AFFORDABLE ALGAE OIL
- COLLABORATING WITH 20 OTHER ORGANIZATIONS
- SELECTED FOR AWARD BY DARPA