GENERAL ATOMICS ALTERNATIVE FUELS

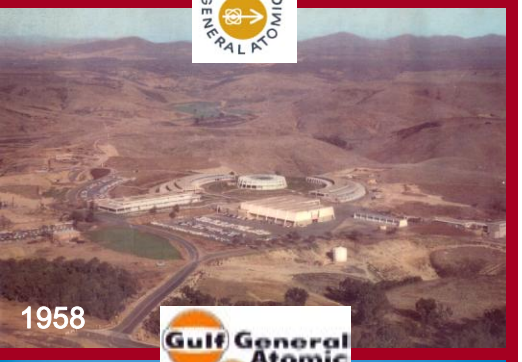
BIOMASS 2011

GENERAL ATOMICS

PRESENTATION OUTLINE

1. Brief overview of General Atomics
2. Algal-derived fuels potential
3. Progress in algal-derived fuels
4. Path to commercialization

GENERAL ATOMICS: OUR HISTORY



FOUNDED:	1955 by GENERAL DYNAMICS
HEADQUARTERS:	SAN DIEGO, CA, USA
CURRENT STATUS:	PRIVATELY HELD CORPORATION

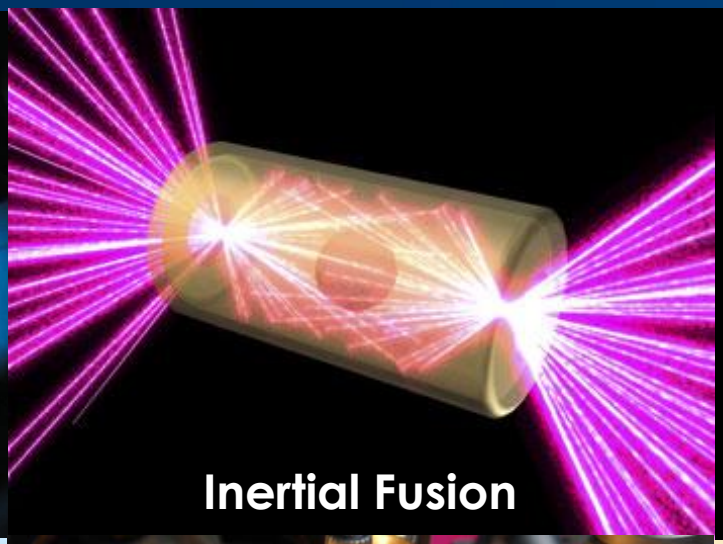
GENERAL ATOMIC

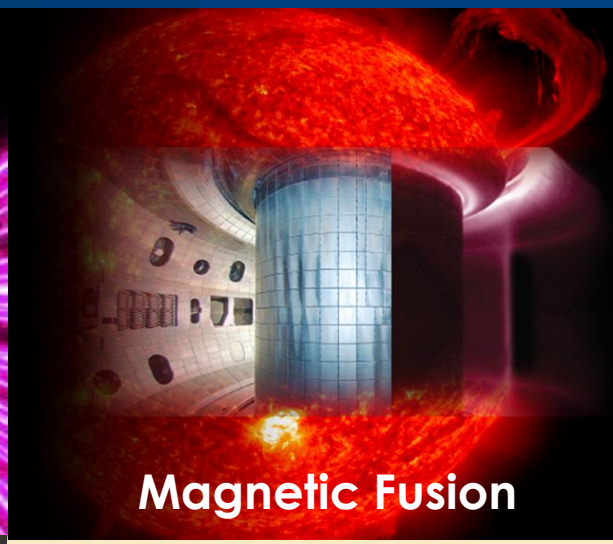
GA Technologies

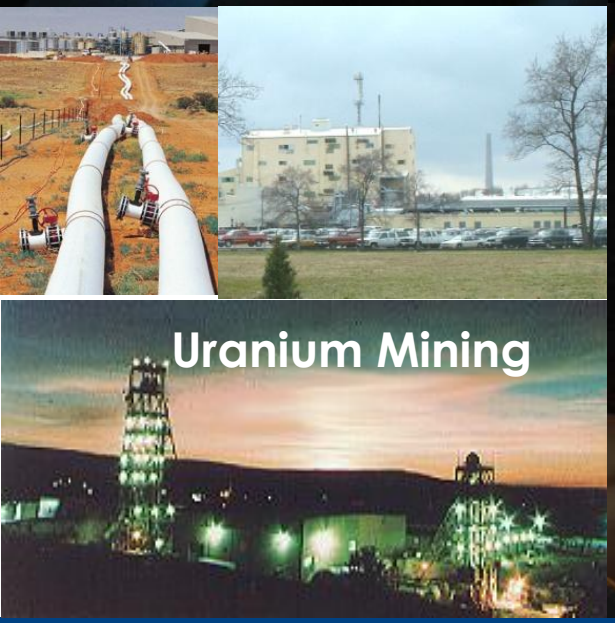
GENERAL ATOMICS

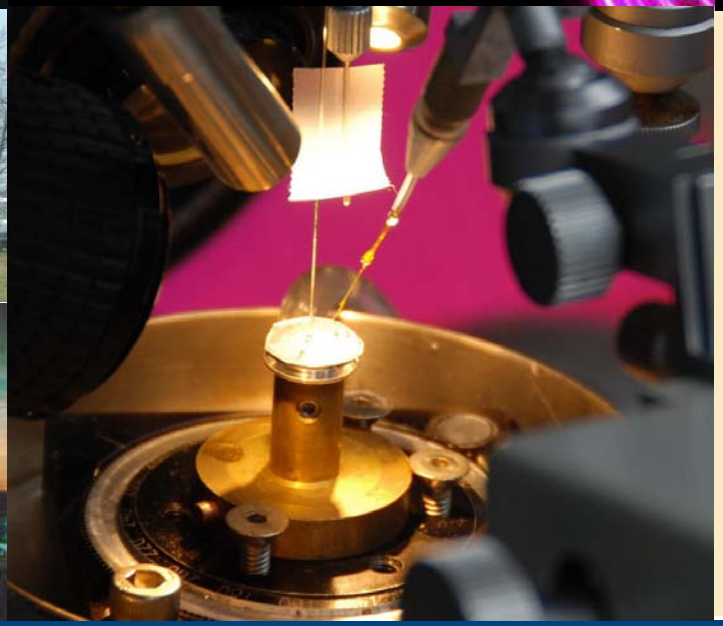
Originally conceived for the purpose of harnessing nuclear technologies for the benefit of mankind, GA and our affiliates are now one of the world's leading resources for high-technology systems development ranging from the nuclear fuel cycle to remotely operated surveillance aircraft, airborne sensors, and advanced electric, electronic, wireless and laser technologies.

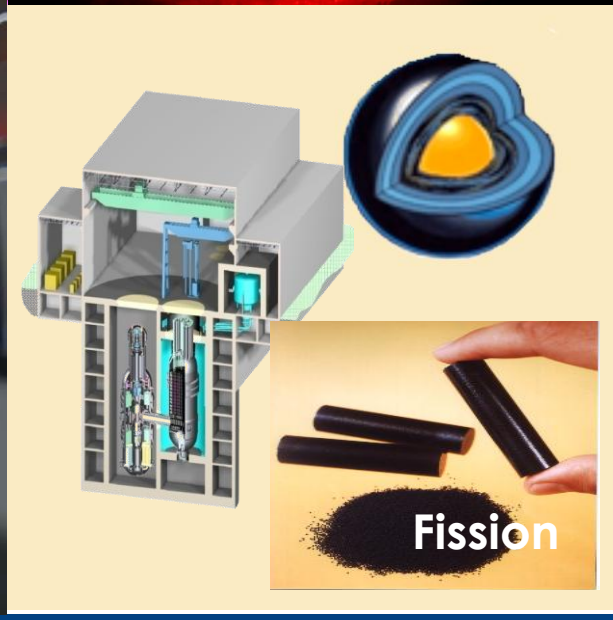
GA'S MAJOR NUCLEAR TECHNOLOGIES



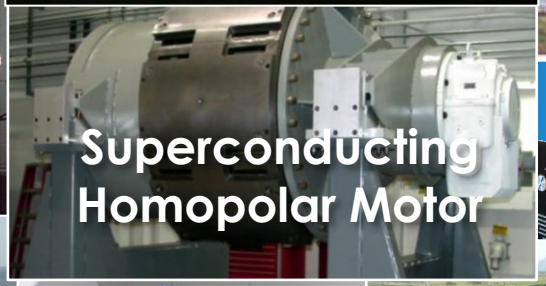








GENERAL ATOMICS DEVELOPS, MANUFACTURES, AND FIELDS ADVANCED TECHNOLOGY SYSTEMS FOR DEFENSE AND ENERGY



UNIQUE POTENTIAL OF PHOTOSYNTHETIC ALGAE BIOFUEL FOR ENERGY INDEPENDENCE

- **Terrestrial Based Biodiesel and Biojet will max out at a few percent of the possible fuel market**
- **Approximately 40 million acres of algae could supply ALL US transportation fuel**
  - US currently uses 970 million acres for crops & grazing
- **Can utilize unproductive land, waste carbon dioxide, and saline water**
- **Economic fuel production is a difficult problem requiring serious effort**

Crop	Oil Gal/Acre/Yr
Soybean	48
Peanuts	113
Rapeseed	124
Coconut	287
Palm Oil	635
Algae	2,000 +

SYSTEMS LEVEL APPROACH STARTED IN 2007 FOCUSED ON ACHIEVING COST METRICS

- **Detailed process and cost model**
  - Drives the research and development program
  - All technology options and process flows
  - Updated as experimental results are generated
- **Technology assessment**
  - Impact on projected cost of production & products
  - Current level of maturity
  - Investment needed to reach baseline level
- **Nimble and efficient approach**
  - Resources focused on maturing areas with greatest impact
  - Rapid evaluation of new technology options
  - Clarity of objectives for technology development

THREE PHASE PROGRAM TO PROVE PROCESS ECONOMICS

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**
  - Demonstrate technical performance and economic viability
  - Collect data for design of commercial facilities

Collaborating with more than 20 other organizations

DARPA ALGAE BIO-FUEL PROGRAM AWARDED DECEMBER 2008

Objectives

- Projected cost of production of JP-8 <$3/gal at 50Mgal/yr
- Commercialization plan that defines a path to reach commercially viable production (both volume and cost) to allow for affordable and widely available fuel

Phase 1 (18 months, 2009-2010)

- <$2/gal triglyceride oil from algae
- Development of dynamic cost models to address location driven market difference
- JP-8 samples, final is 100 liters

Phase 2 Option (18 months, 2010-2011)

- Targeting technology scalability demonstrations
- <$1/gal triglyceride oil from algae
- JP-8 samples, final is 4000 liters

HAWAII SYSTEM ON KAUAI, ALGAE PRODUCTION EARLY 2010 – DARPA FUNDED

Distribution Statement A
(Approved For Public Release, Distribution Unlimited)

PHASE 1 OVERALL PROGRAM METRICS

Phase	Months After Contract Award	Program Metrics Topic Area 2: Affordable Algal Oil for JP-8
1	18 Months	1. <$2/gal triglyceride oil from algae 2. Projected cost of production of JP-8 <$3/gal at 50Mgal/yr
2	18 Months	1. <$1/gal triglyceride oil from algae 2. Projected cost of production of JP-8 <$3/gal at 50Mgal/yr

Phase 2 was awarded

Distribution Statement A
(Approved For Public Release, Distribution Unlimited)

KAUAI ALGAE FARM CONSTRUCTION
MAY 23, 2011

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SUMMARY OF FINANCIAL MODEL RESULTS

- At scale, good projected returns are attained
- Modest technology improvements make the projected returns very attractive
- The high internal rates of return will lead to commercial investment once the risk is lower
- Projected returns are good enough to justify striving to reach commercial scale as soon as possible

INITIAL COMMERCIAL FACILITY NEEDED TO ENABLE RAPID INDUSTRY DEVELOPMENT

- **Initial plant key to rapid commercialization**
  - Demonstrate economic viability
  - Establish product markets

- **Difficult to finance**
  - High scale-up risk
    - Process scale up: ~100x
    - First-of-a-kind: no other comparable systems
    - Biological: large, concentrated population of one species
  - Creating a new industry, supply chain and markets
  - Too small for full economies of scale
  - Too expensive for typical venture capital and not technology development

CONCLUSION

- Achieving the technical and cost objectives
- Detailed cost and financial model supports the tremendous commercial potential of algal biofuels
- Financing is very challenging for the first commercial-scale algae biofuel farm
- Business case is strong, so commercial investment will follow once the risk is reduced by operation of the first facility