The Role of Fischer Tropsch Fuels for the US Military

U.S. AIR FORCE

30 Aug 2006

William E. Harrison III
National Aerospace Fuels Research Complex
Air Force Research Laboratory
Wright-Patterson AFB OH
Senior Advisor, ODUSD (AS&C)
william.harrison@wpafb.af.mil

OSD Assured Fuels Initiative

Vision: DoD/AT&L intends to catalyze commercial industry to produce clean fuels for the military from secure domestic resources using environmentally sensitive processes as a bridge to the future.

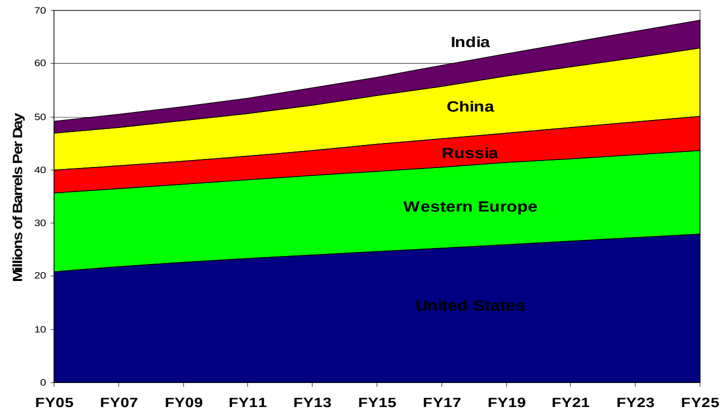
AFRL – 06-0078

Briefing Outline

- DoD Energy Concerns
- Fuel Facts and Figures
- Fischer Tropsch Fuels
- Air Force Focus on Energy and Alternative Fuels
- B-52 Flight Demo
- AF Fleet Qualifications
- Impact on Advanced Systems
- Summary

Strategic Issues

- World Oil Demand is Rising
- On Cusp of Supply/Demand



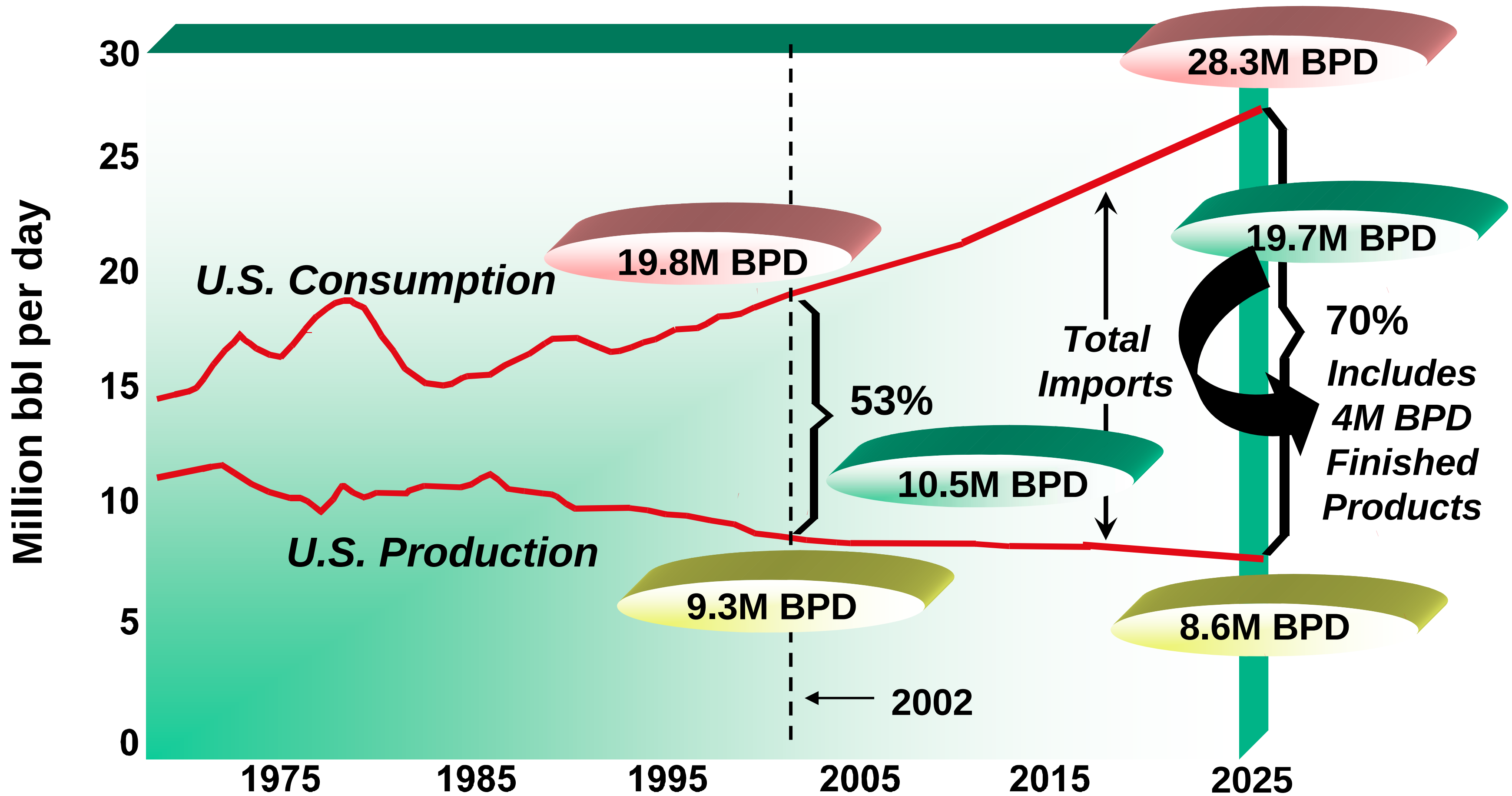
Source: Energy Information Administration, Department of Energy

- U.S. Energy and Economic Security is Increasingly at Risk
- World Oil Supply May Soon Peak and Decline
- Military Preparedness and Homeland Defense Requires Secure Fuel Sources
- Current Energy Policy Relies Heavily on Imported Foreign Oil
- America's Unconventional Fuel Resources Can Help Bridge the Gap to Future Fuels

"America is addicted to oil, which is often imported from unstable parts of the world. The best way to break this addiction is through technology….new technologies will help us reach another great goal: to replace more than 75 percent of our oil imports from the Middle East by 2025."

George W. Bush
Jan 31, 2006
State-of-the-Union Address

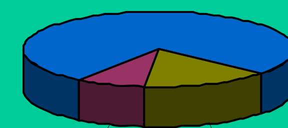
Increasing Reliance on Petroleum Imports



Source: EIA (AEO 2004); Reference Case Scenario
[Courtesy John Winslow-DoE]

DOD Energy Concerns

- **Lack secure and reliable sources of energy**
  - **Dependent on foreign oil**
  - **Becoming dependent on foreign refined fuels**
- **Supply chain vulnerability**
  - **Rely on mega-refineries**
  - **Vulnerable to terrorist threats or natural disasters**
- **Need for cleaner fuels**
  - **DoD exempt from some EPA regulations**
- **Need for Better Fuels**
  - **Thermal stability, advanced engines, fuel cells**
- **Need for Fewer Fuels**
  - **9+ Fuels presently in AOR**
- **Potential limits on deployments**
  - **Possible conflict with EU rules**



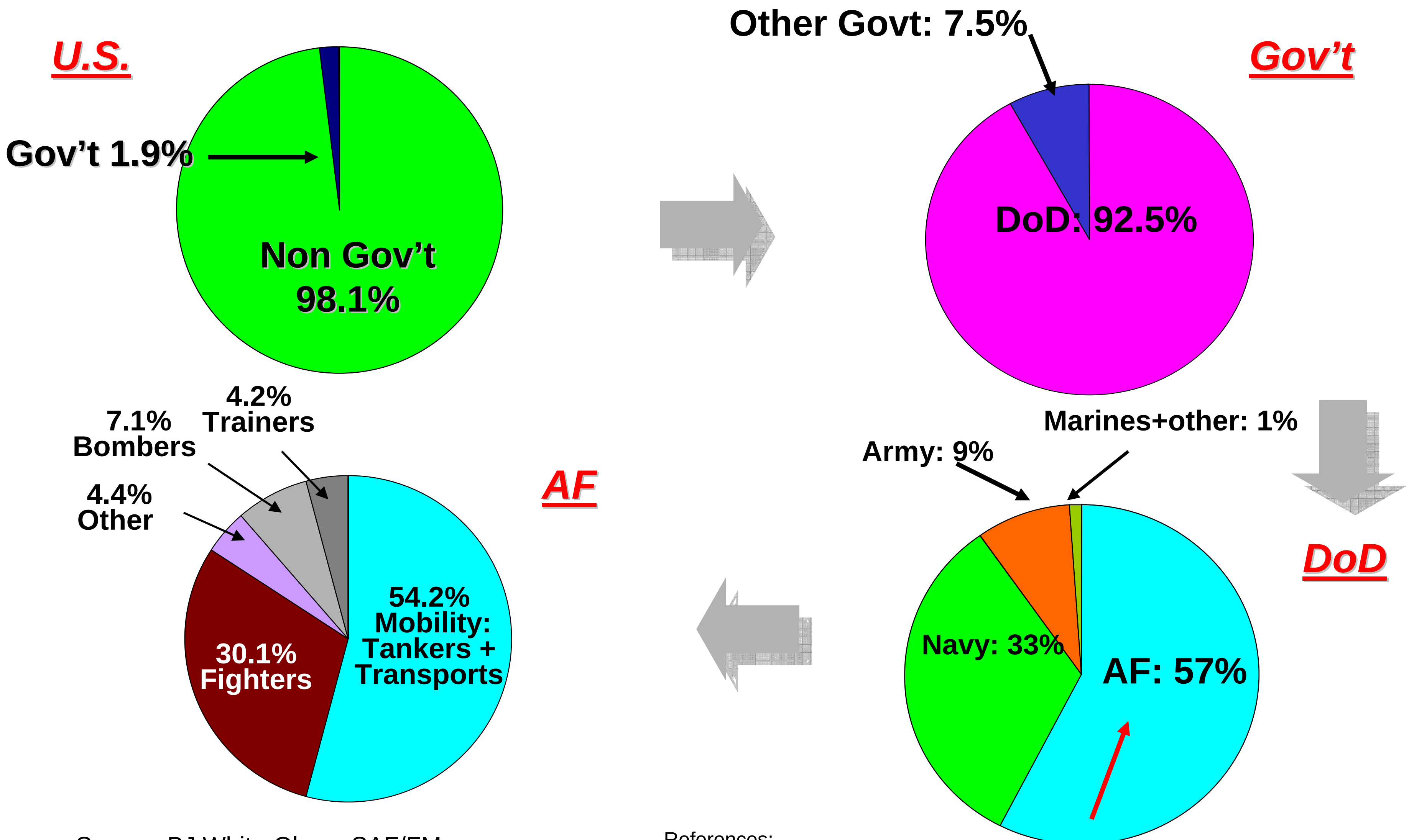
Military Demand
Approx 2% of US Consumption

Approx: 300,000 bbl/ day of 20M bbl/day Total

"DoD intends to catalyze the commercial industry to produce clean fuels for the military from secure domestic resources using environmentally sensitive processes to enable a bridge to the future."

Theodore K. Barna, Ph.D.
Assistant Deputy Under Secretary of Defense/
Advanced Systems and Concepts

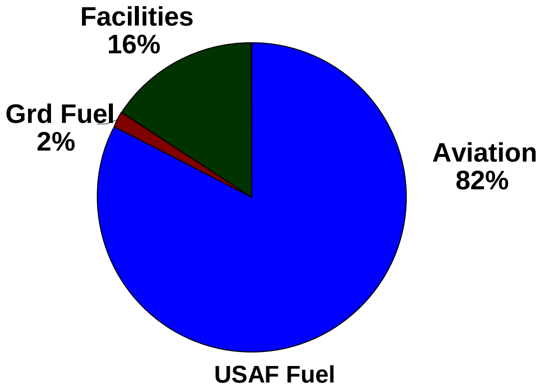
US Govt / DOD / AF Fuel Utilization (FY04)



Source: BJ White-Olsen, SAF/FM

References:
1) DOE Annual Energy Review, Aug 2005 (available on-line).
2) DESC FY04 Fact Book (available on-line)

Air Force Energy Use (cost)



3.2 B gallons

American 3.2 B

United 2.3 B

Delta 2.1 B

Northwest 1.7 B

Continental 1.3 B

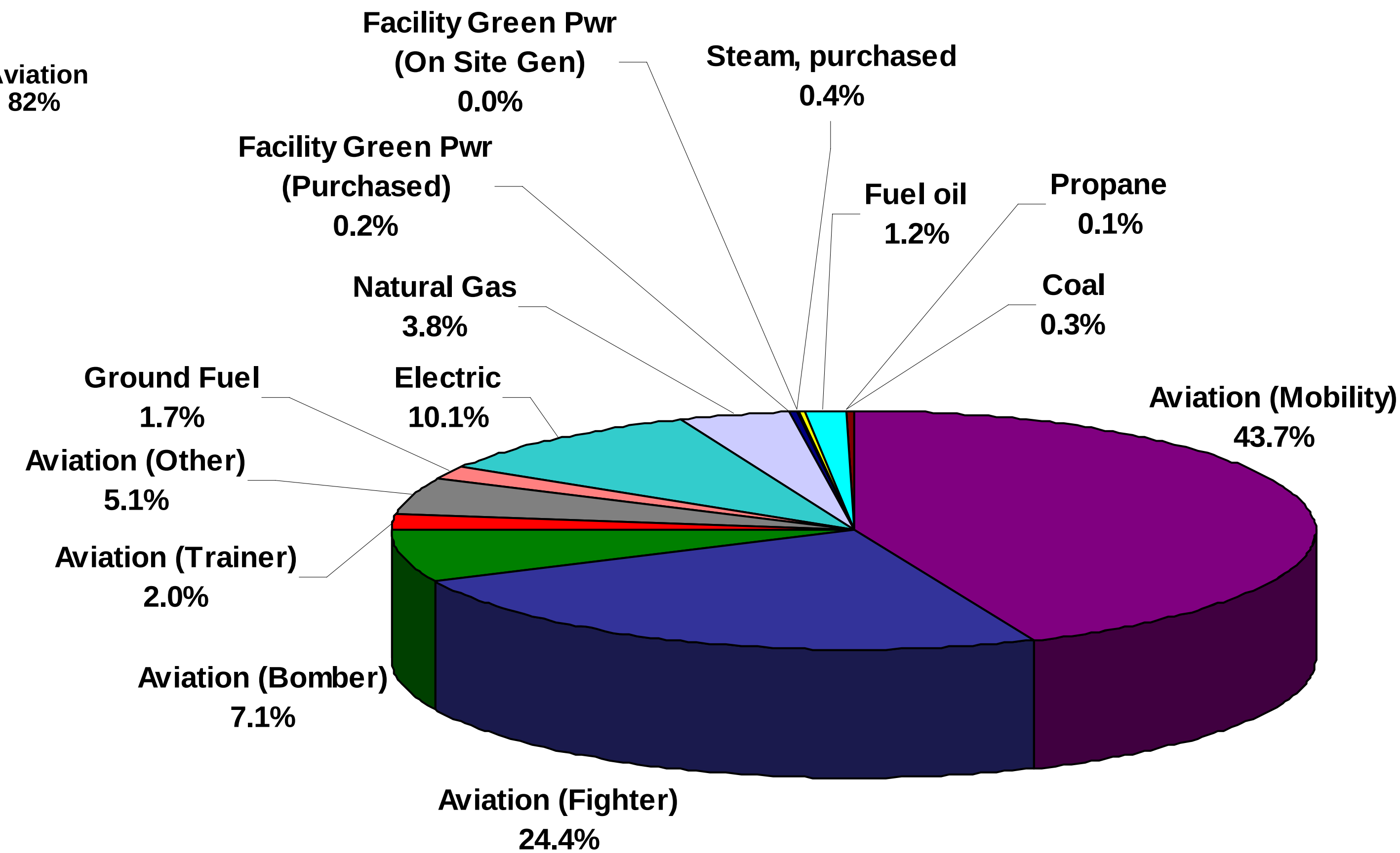
Southwest 1.3 B

Fed Ex 1.1 B

US Airways 0.9B

UPS 0.6 B

2005 Usage
Jet Fuel Intelligence
May 2005



AF Energy Bill (Fuel) exceeds $10M per day

Every $10/barrel increase drives up AF fuel costs $600M per year

Establishing the AF Vision

- Provide leadership in developing energy options to increase warfighting capability
  - Enable secure and reliable energy alternatives
  - Increase energy use efficiency
  - Reduce life cycle costs

Acquisition & Technology Near & Mid Term

- AFRL IPT on Energy Stood up
- Alternative Fuels Initiative (Coal, Nat'l Gas, Oil Shale, BioMass)
  - Flight Demonstration (Summer / Fall 06)
  - Joint DOD/DOE Assured Fuels Study & Report to Congress (Jun 06)
- Aircraft Technology Improvement Initiative
  - Engine Technology - Versatile Affordable Advanced Turbine Engine (VAATE) program: Specific Fuel Consumption Reduction Goal of 25%
  - Aircraft Structures: Survivable Integrated Inlet, Advanced Aluminum Aero Structures, Ultra-lightweight Multifunctional Airframe
- Modernization Initiatives and Studies
  - SAB Study on Improved Air Vehicle Efficiency (Complete- Feb 06)
  - NRC Propulsion Study (Underway, Jul 06)
  - AFMC Re-engine Study (Underway, Dec 06)
  - C-5 Reliability Enhancement and Re-engine Program (In POM)
  - AWACS, OC-135s, etc Re-engine (In POM)
  - A-10 Re-engine (In POM)

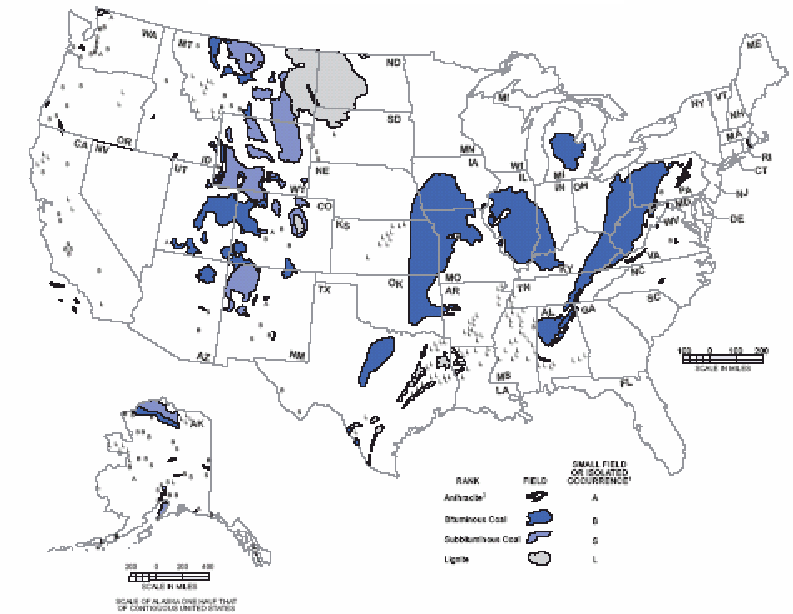
Highlighted initiatives

AF Energy Strategy
Addressing Supply & Demand

- **Make energy a consideration in all Air Force actions**
- **Promote a culture where Airmen conserve energy**
- **Accelerate development and use of “Alternative” fuels**
- **Mitigate energy-related Critical Infrastructure Program vulnerabilities and risks that impact Air Force Operations**

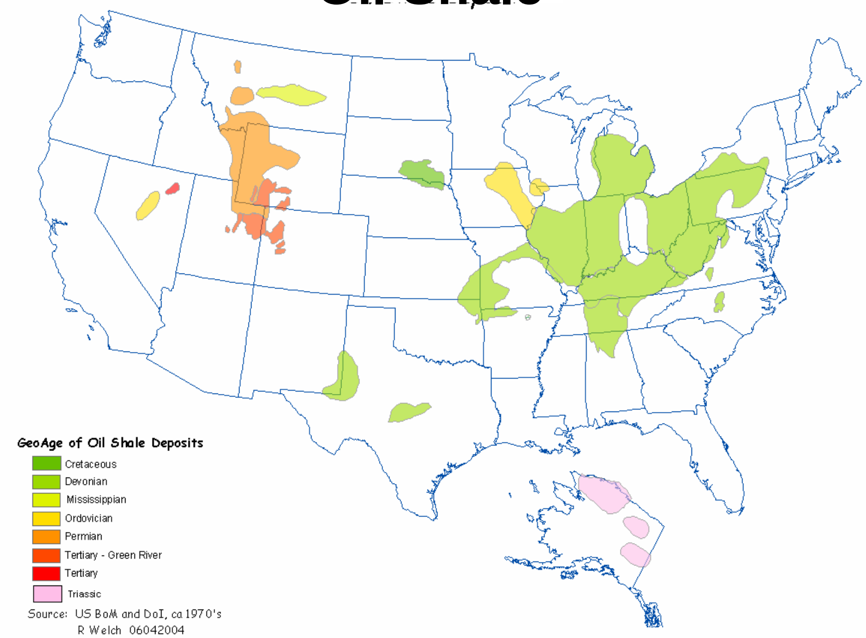
US Energy Resources

Coal

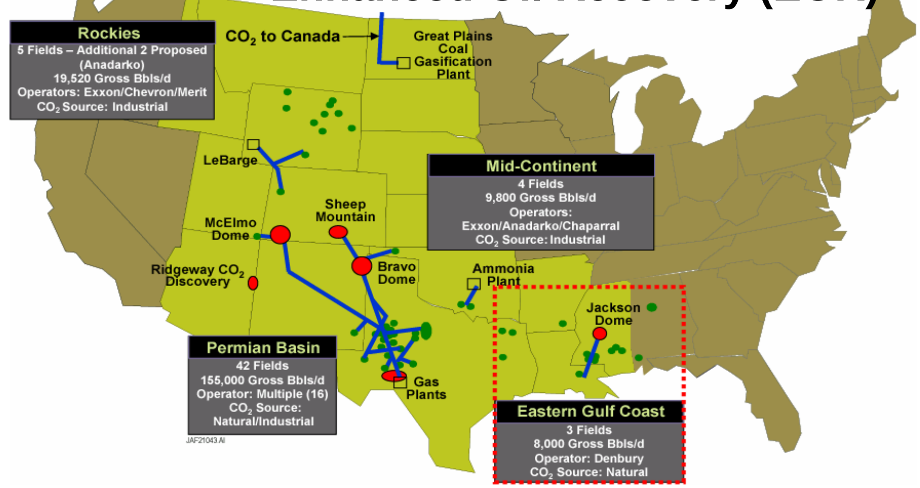


Sources: United States Geological Survey, *Coalfields of the United States, 1960-1961*; Texas Bureau of Economic Geology, *Lignite Resources in Texas, 1980*; Louisiana Geological Survey, *Near Surface Lignite in Louisiana, 1981*; Colorado Geological Survey, *Coal Resources and Development Map, 1981*; and Mississippi Bureau of Geology, 1983.

Oil Shale



Enhanced Oil Recovery (EOR)



Domestic Resources

- **1.4 trillion barrels (shale)**
- **900 billion barrels of FT (coal)**
- **0.15 billion barrels (pet coke)**
- **22.7 billion barrels oil reserves**
- **240 billion barrels of oil (EOR)**
- **100 million pounds of pulp waste/year**

Total 2.3+ trillion barrels equivalent

Fuels From Alternate Sources

We Could Be the New Middle East
2.3+ Trillion Barrels

Saudi Arabia:	261.8 Billion Barrels
Iraq:	112.5 Billion Barrels
UAE:	97.8 Billion Barrels
Kuwait:	96.5 Billion Barrels
Iran:	89.7 Billion Barrels
Qatar:	15.2 Billion Barrels
Oman:	5.5 Billion Barrels
Yemen:	4.0 Billion Barrels
Syria:	2.5 Billion Barrels

TOTAL 685.5 Billion Barrels

Domestic Sources
Coal and Shale

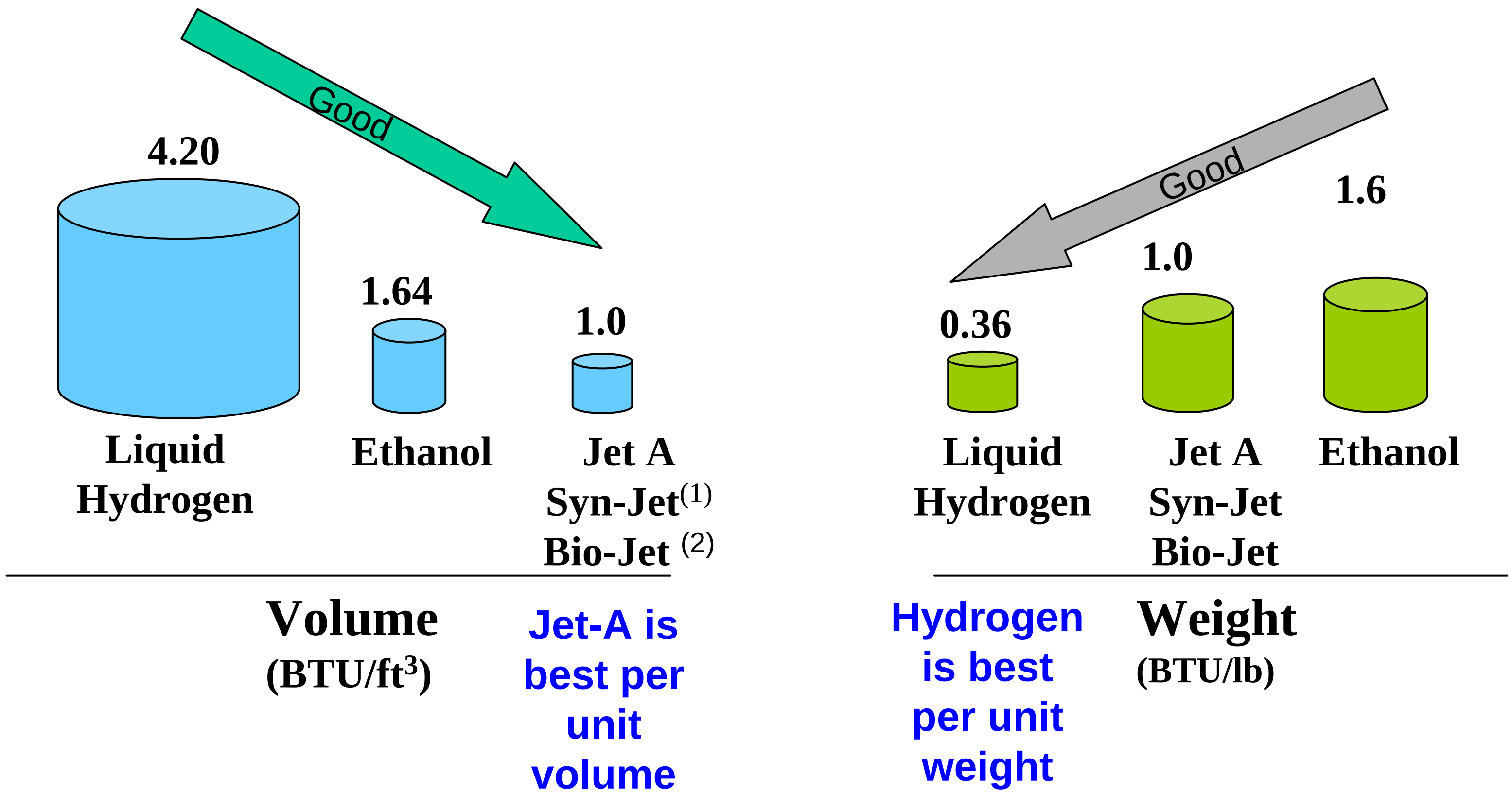
Appalachian States	0.9+ T Bbls
Western States	1.4+ T Bbls
TOTAL:	2.3+ T Bbls

TOTAL 2.3+ T Bbls Equivalent

OSD Total Energy Development (TED)
All Sources of Energy

- Coal Fuels: **Outreach to industry**
  - **Mining, gasification, power production, Fischer Tropsch production, chemical production, product distribution**
- Shale Fuels: **Co-Chair DOE/DOD task force**
  - **Evaluate Latest Technology**
  - **Coordination with DOE (Hq Fossil Energy, NETL) and Dept of Interior**
  - **Briefed House and Senate Energy Committees**
- Biomass Fuels: **Trees**
  - **Identified potential with pulp and paper industry and US Forrest Service**
  - **Coordinating activities with American Forest and Paper Association**
- CO_2 for Enhanced Oil Recovery: **Economics and Environment**
  - **Climate Vision – Presidential Initiative**
  - **DOE Programs and Industry development**
- Technology Evaluation: **Poly-generation**
  - **Gasification, Fischer Tropsch wax production, wax upgrading**
  - **Transportation fuels, power production, chemicals, and fertilizer**
  - **For example: Chevron/SASOL, Shell, UOP, RenTech, Syntroleum, Eastman Chemical, Southern Companies, Royster Clark, HTI**
- Monitoring Congressional Legislation
  - **Energy, Transportation, Defense**
  - **EPAct legislation that affects DoD**
  - **National Defense Authorization Act**

Aircraft fuel needs to have a high energy content per unit volume and weight



***Equivalent Energy**

Chart from Dave Daggett -- Boeing Company

(1) Synthetic Jet fuel such as from Fisher-Tropsch process

(2) Bio-derived jet fuel similar to a refined bio-diesel fuel

AFRL – 06-0078

Hydrogen airplane needs large fuel tanks, which reduces its fuel efficiency (on smaller airplanes)

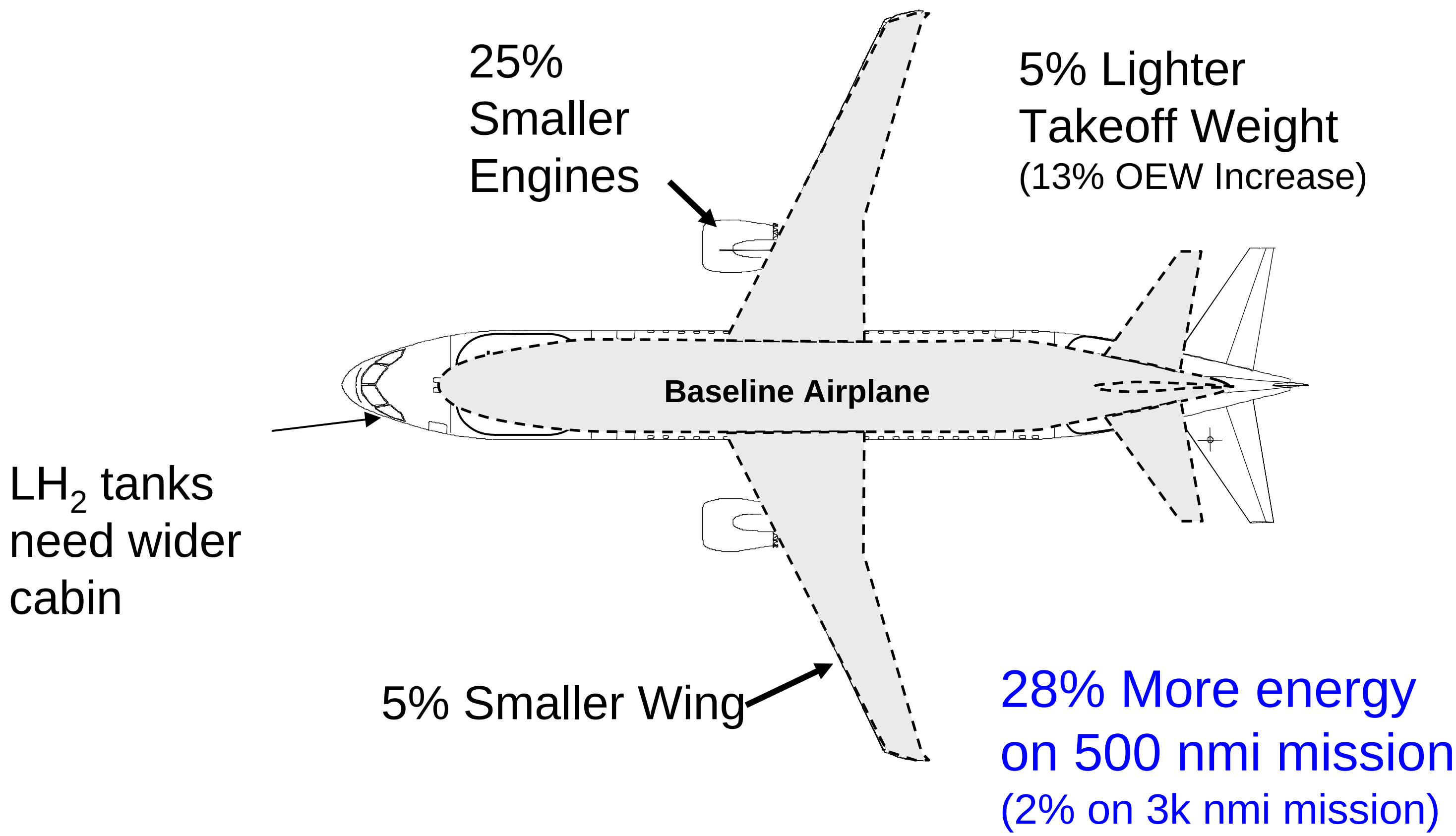
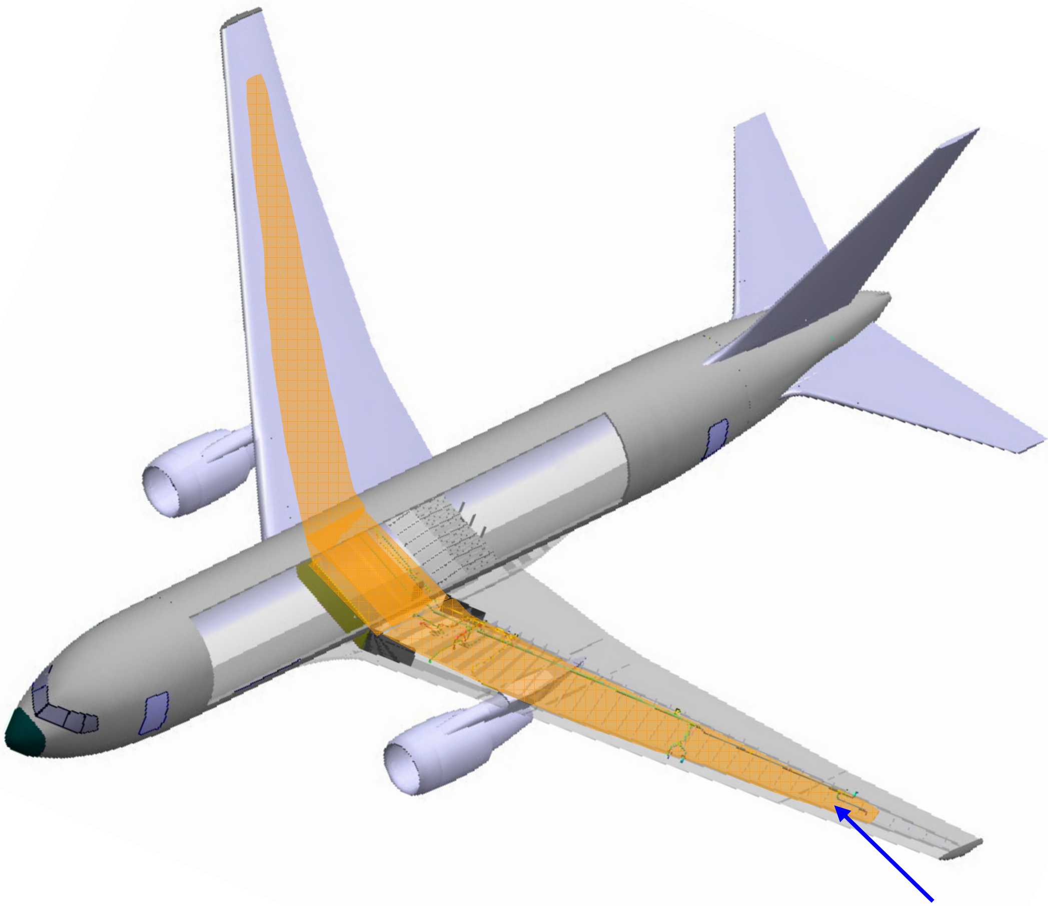


Chart from Dave Daggett -- Boeing Company

Liquid, non-cryogenic fuels are easily stored on present airplanes

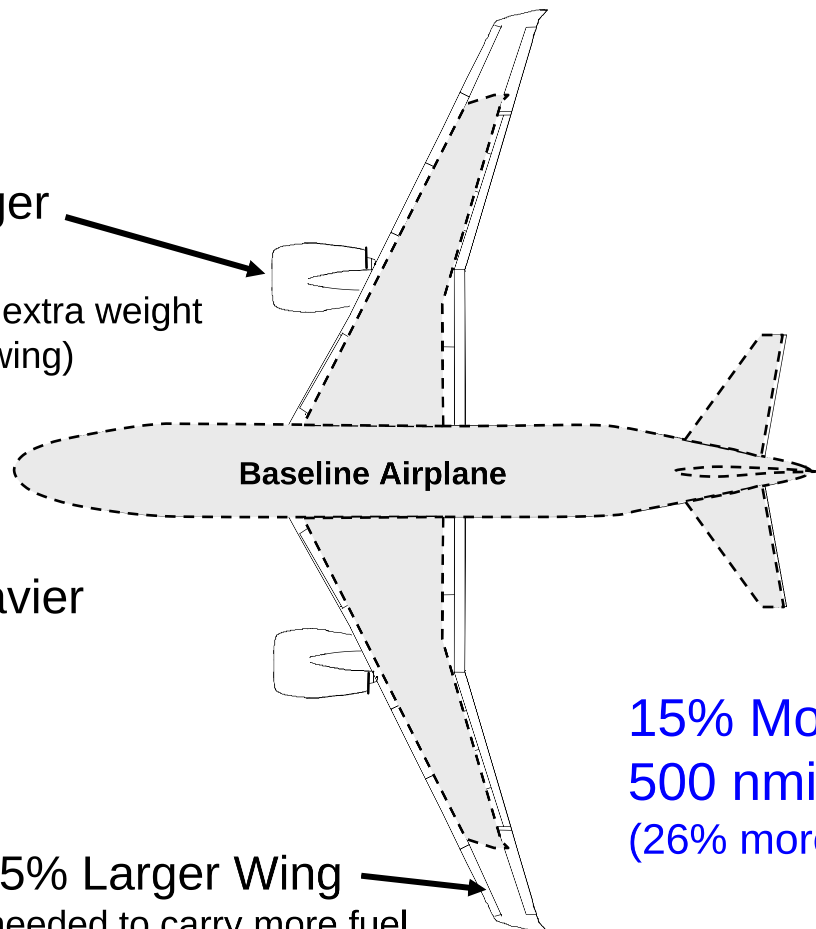


Jet fuel tanks are integral with wing structure

Chart from Dave Daggett -- Boeing Company

Ethanol fuelled airplane will require much larger wings & engines; reducing its fuel efficiency

50% Larger Engines
(needed for extra weight of fuel and wing)



35% Heavier Takeoff Weight
(20% OEW Increase)

25% Larger Wing
(needed to carry more fuel since it contains less energy*)

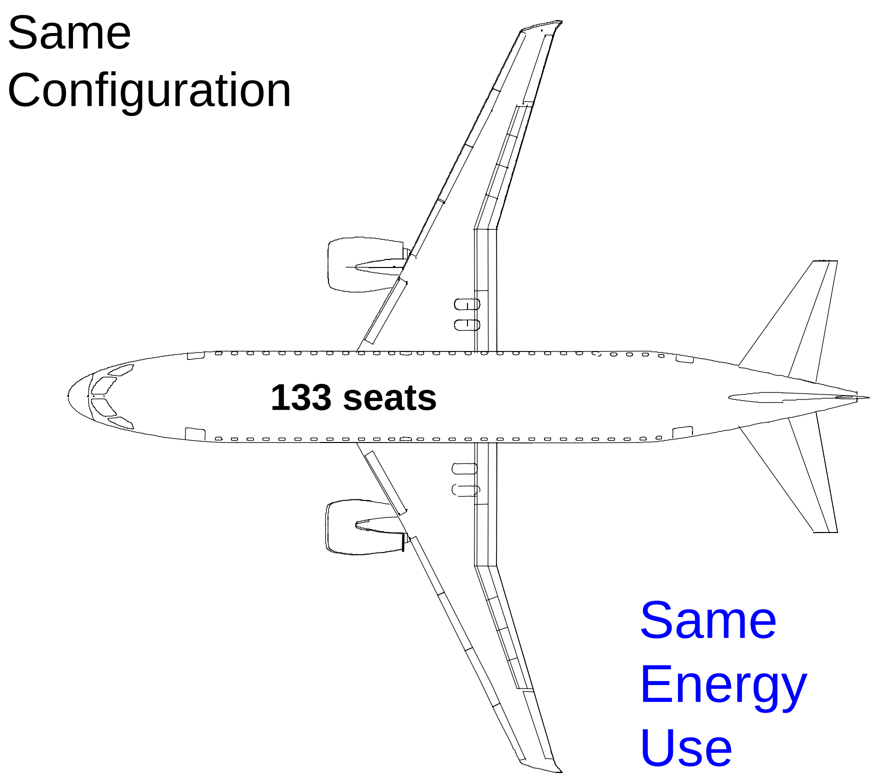
15% More energy use on 500 nmi mission
(26% more on 3K nmi mission)

*Ethanol only has 60% the energy content of Jet-A

Chart from Dave Daggett -- Boeing Company

Ethanol Airplane

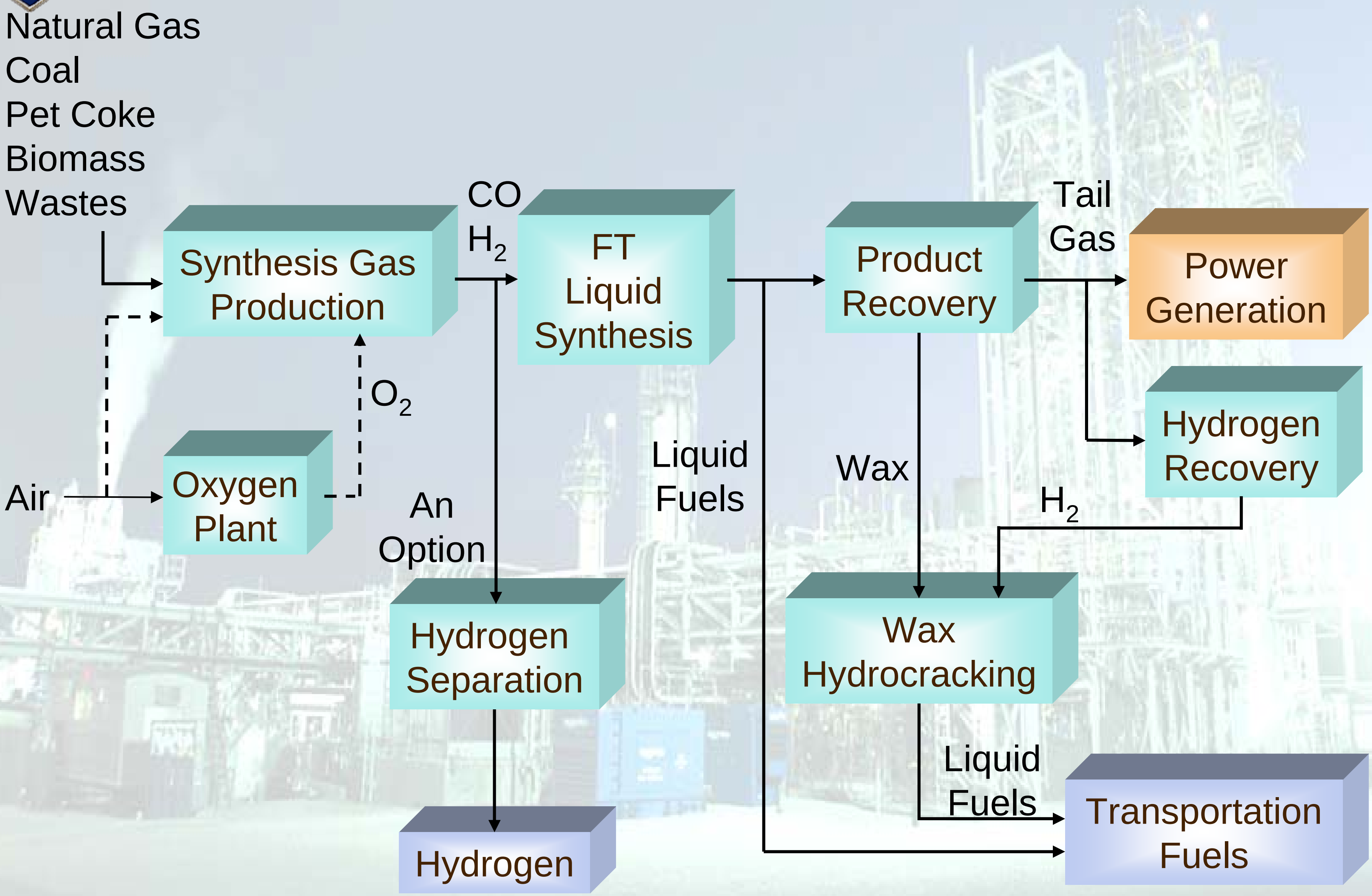
Synthetic or Bio-Jet Fuel will not change the airplane configuration or its fuel efficiency



Synthetic GTL or Bio-Jet Fuel Airplane

Chart from Dave Daggett -- Boeing Company

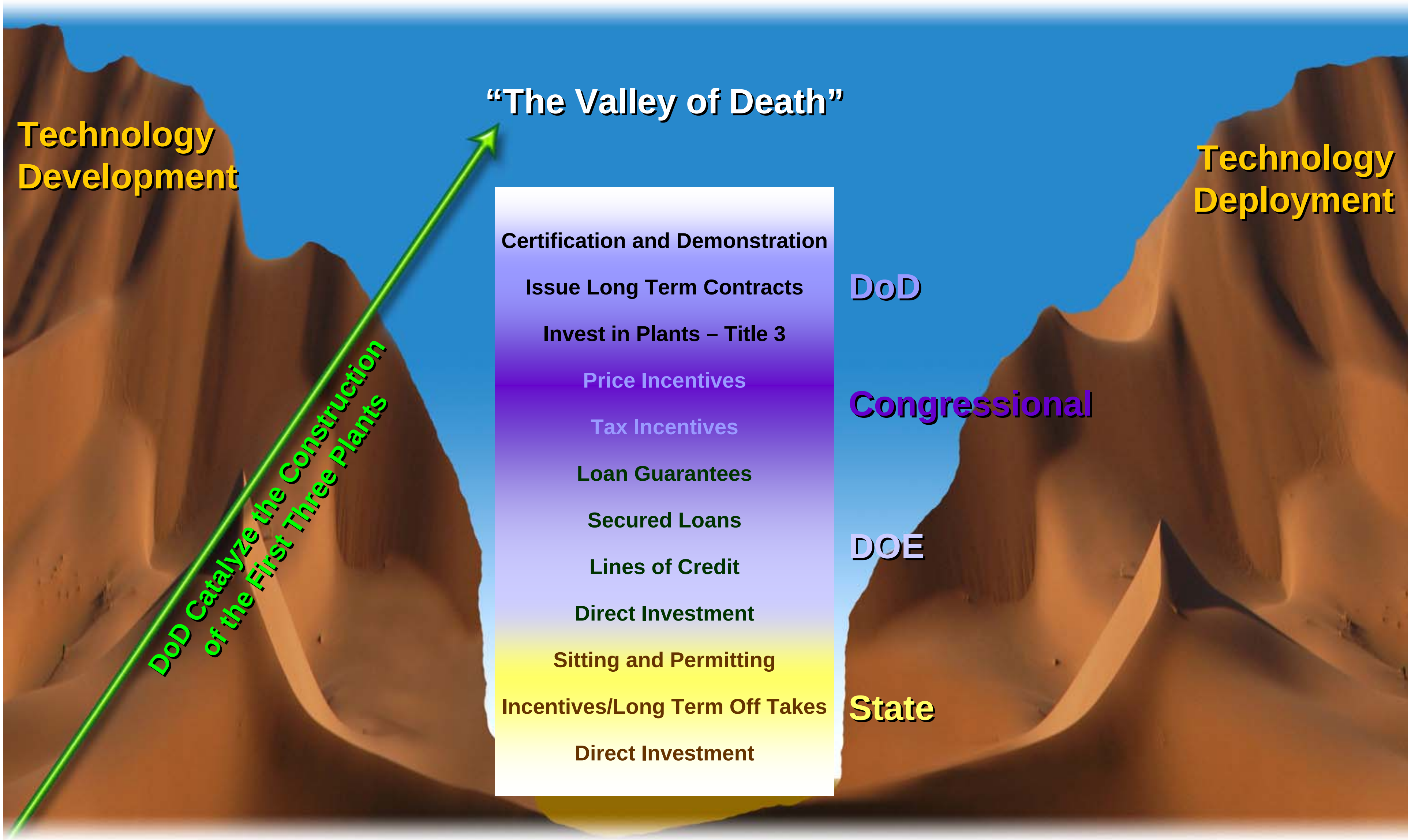
Fischer-Tropsch Technology



Hurdles and Impediments

DoD leadership key to bridging the "Valley of Death" to obtain secure, domestic sources of fuel

Industry Needs DoD Leadership



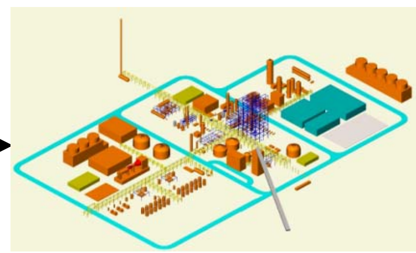
Value Added Choices For Coal

A choice to make:

1 ton of Il. Coal $32/ton

Combustion
Gasification

Gasification



Gasification

Electric Power Production

Products	Value
2 MWh electricity	$70.00
Total	**$70.00**

FT Fuels and Power

Products	Value
0.41MWh electricity	$14.00
0.34 bbls naphtha	$15.00
1.36 bbls jet fuel	$81.00
Total	**$110.00**

Fertilizer, FT Fuels and Electric Power

Products	Value
0.07 MWh electricity	$ 0.23
0.17 bbls naphtha	$ 8.00
0.78 bbls jet fuel	$46.50
0.25 tons of ammonia	$87.00
Total	**$141.73**

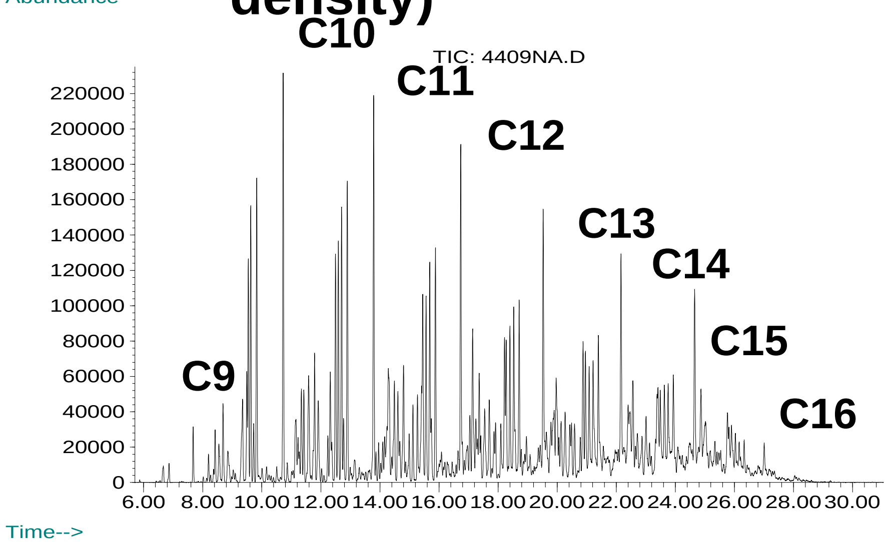
Projected Numbers RenTech

Research Participants

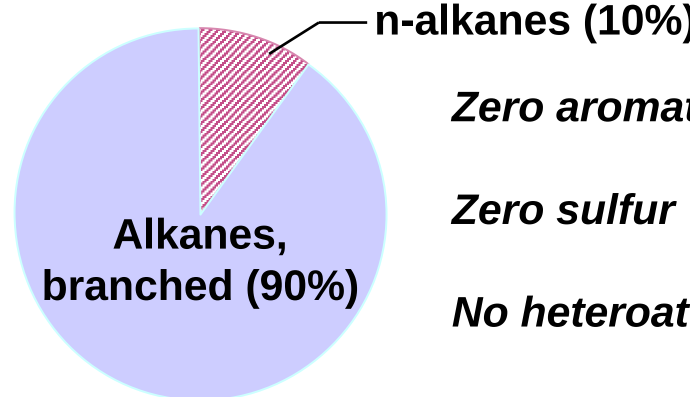
- Air Force
  - Air Force Fuels Research Laboratory/NAFRC
  - University of Dayton Research Institute
- Army
  - TARDEC Fuels & Lubricants Laboratory
  - Southwest Research Institute
- Navy
  - NAVAIR Fuels and Lubricants Laboratory
  - Naval Fuels and Lubricants Integrated Product Team
- DoE
  - National Energy Technology Laboratory
- Syntroleum Corp.

FT Fuels Reduce Emissions

- **Less Pollutant Emissions**
  - **2.4% less CO_2**
  - **50% to 90% less particulate matter (PM)**
  - **100% reduction in SOx**
  - **~1% less fuel burn (increased gravimetric energy density)**



Hydrocarbon types in Syntroleum S-5



Zero aromatics

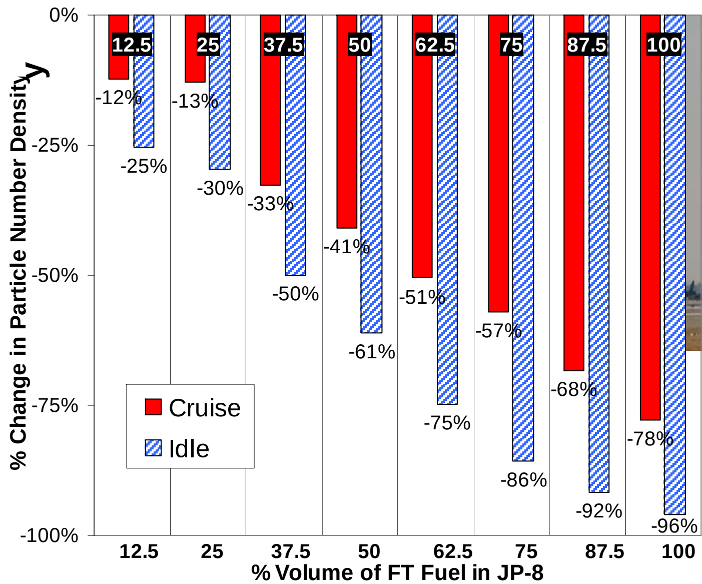
Zero sulfur

No heteroatoms

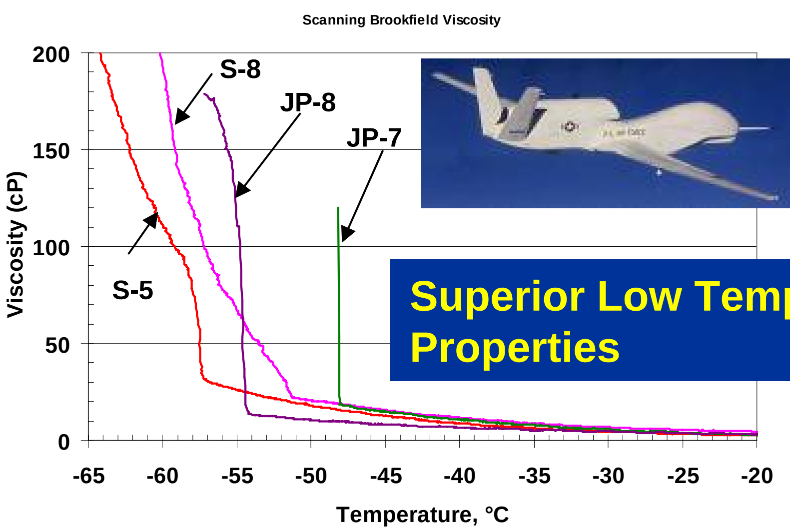
Highly Paraffinic Fuel – normal and isoparaffins

Petroleum derived fuels are rich in aromatics, cycloparaffins, and heteroatoms

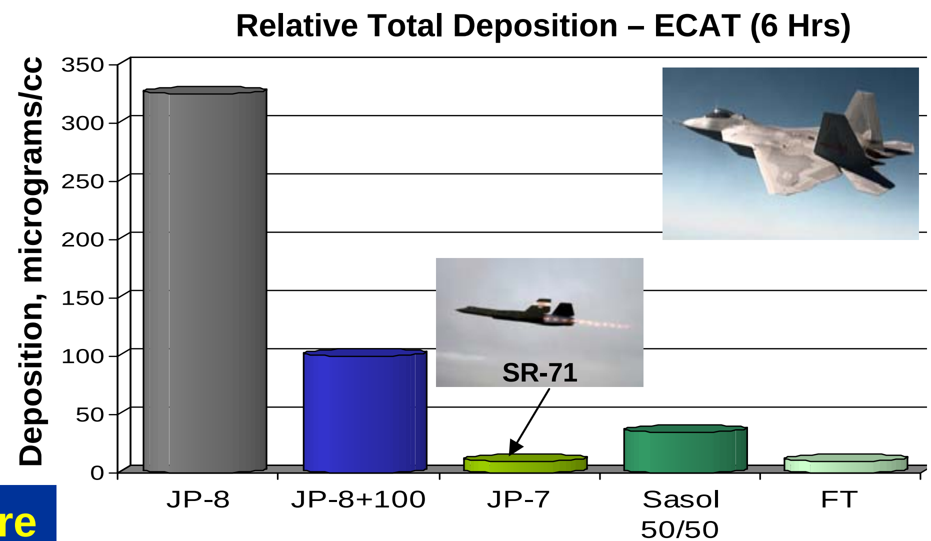
Fischer-Tropsch Fuels
-- Benefits --



Significantly Reduced Emissions

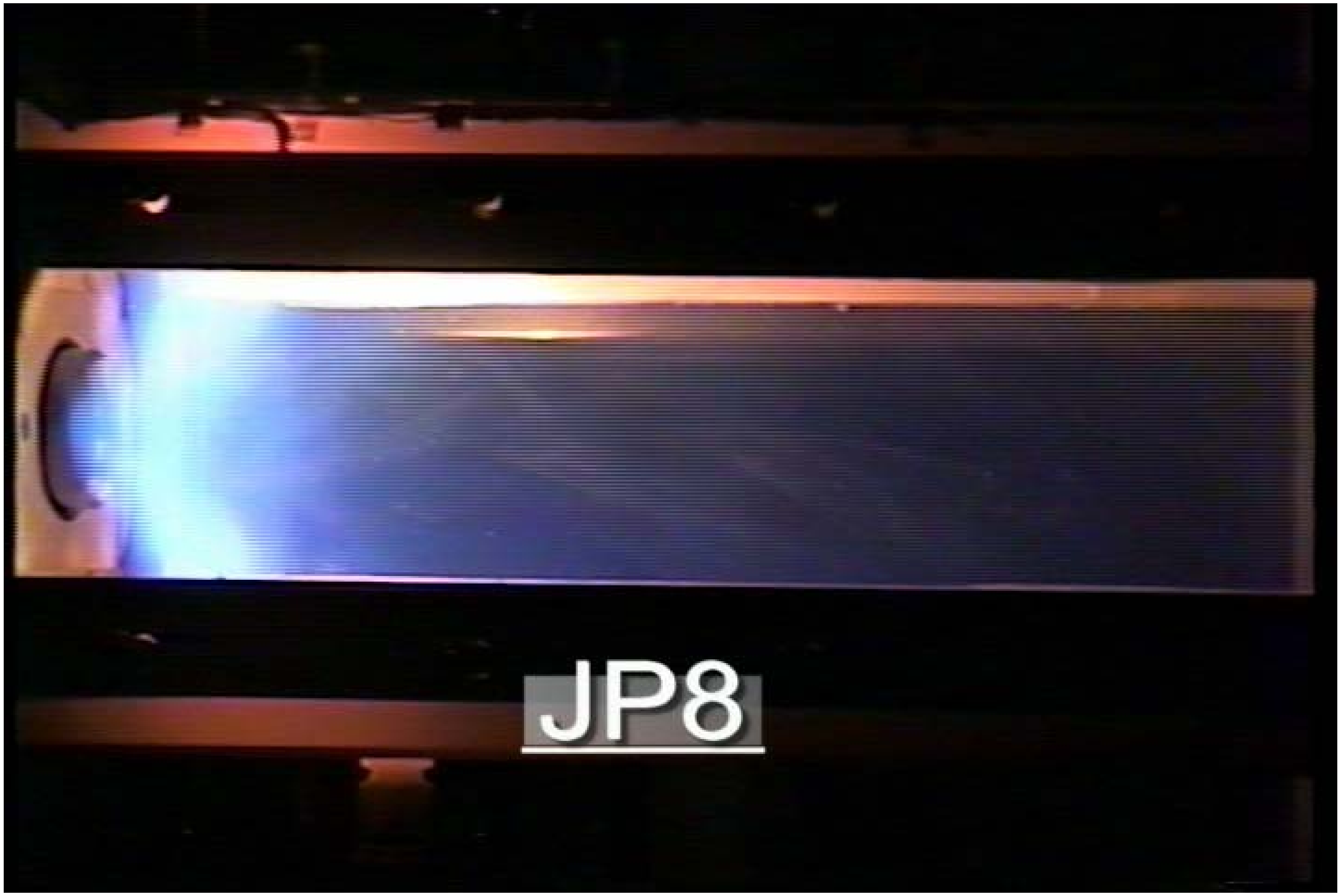


Superior Low Temperature Properties

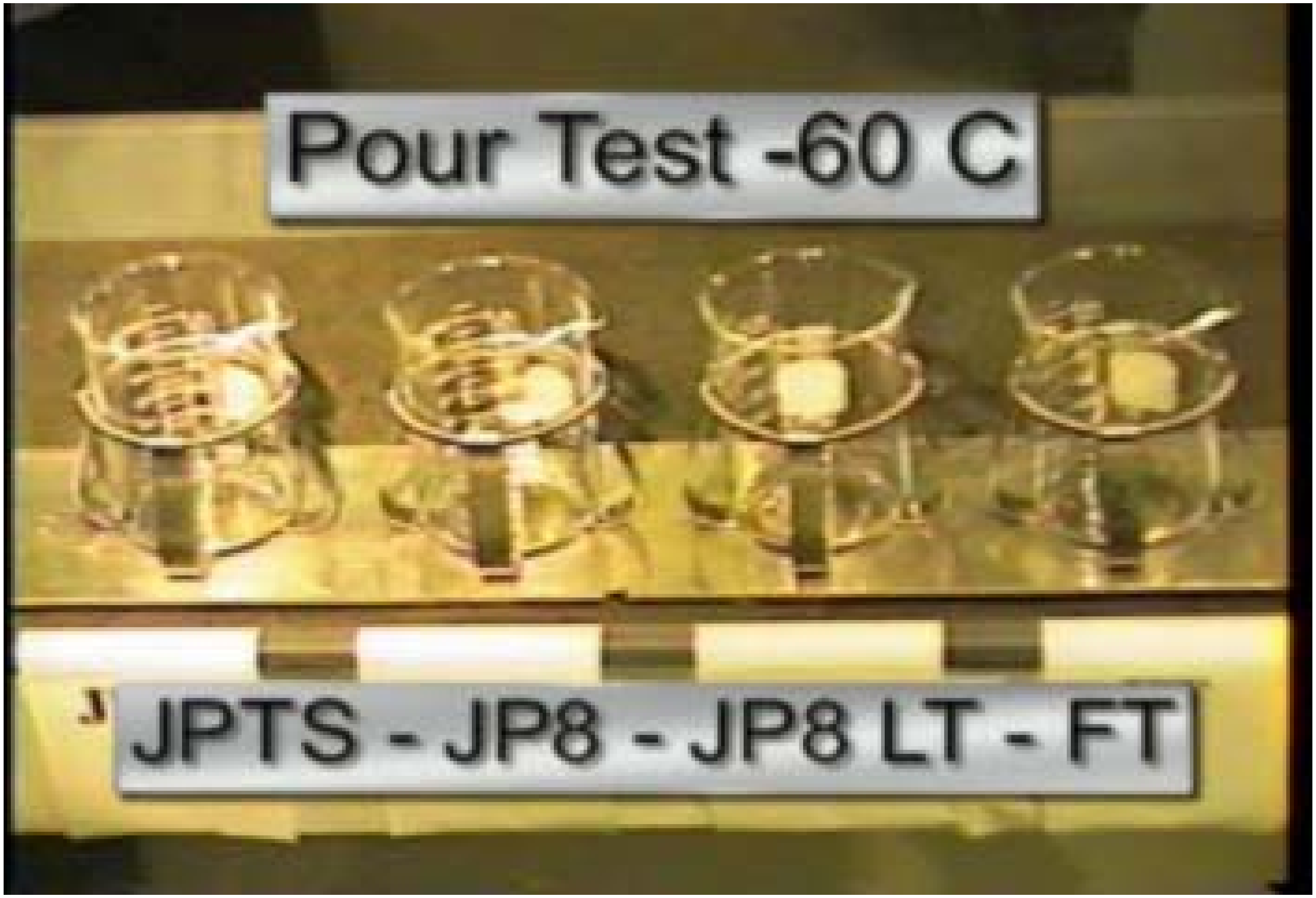


Excellent Thermal Stability at High temperature

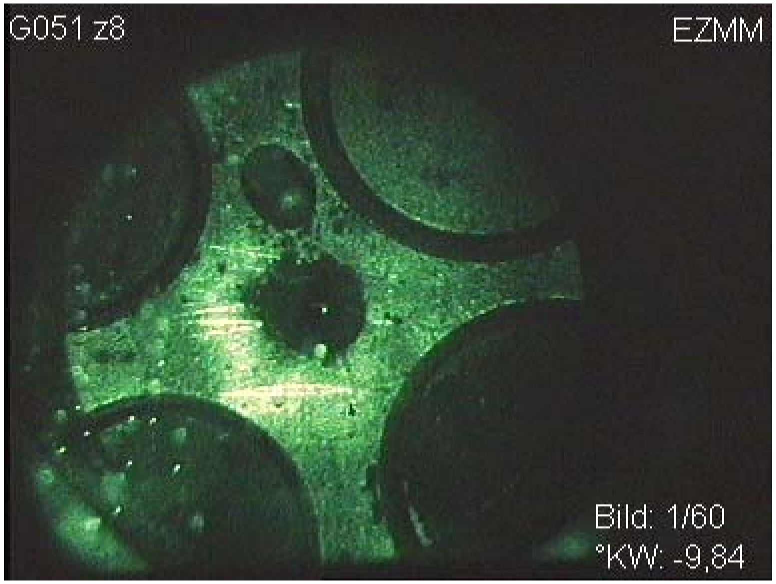
Combustion Test CFM-56 Nozzle Rig
Syntroleum S-8



Low Temperature Characteristics Syntroleum S-8



FT Diesel Testing Volkswagen Tests



Petroleum

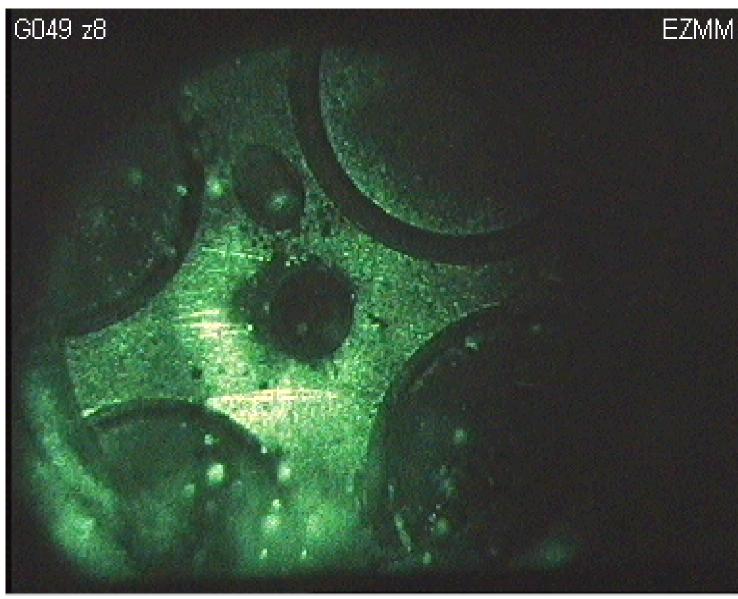
Diesel

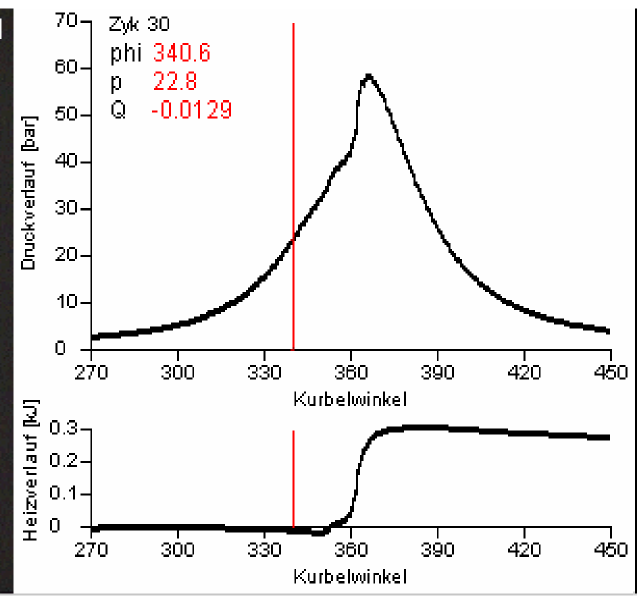
Fuel

Fischer Tropsch

Diesel

Fuel





Task

- Secretary of the Air Force request: Demonstration of F-T fuel in manned Air Force aircraft this summer
- Air Force Materiel Command (AFMC) is lead organization
- AFMC to define steps after demo

B-52 and Legacy Fleet

Objective:

Develop a JP-8/FT fuel blend that is *fully interchangeable* with JP-8 fuel – conservative approach based on SASOL experience

Fully Interchangeable:

Operationally, fuel should behave exactly like JP-8. There should be no adverse effects resulting from switching from one to the other.

- Conforms to JP-8 Specification (meets spec does not mean fit for purpose)
- Meets Performance Requirements
  Elastomer Compatibility
  Lubricity
  Airframe compatibility
  Engine Operability

Blend Strategy

- Fischer-Tropsch fuels contain same *n-* and *iso*-paraffins as JP-8, but contain no aromatics, cycloparaffins, or sulfur compounds
- F-T fuels w/ JP-8 additives meet all JP-8 spec requirements except density

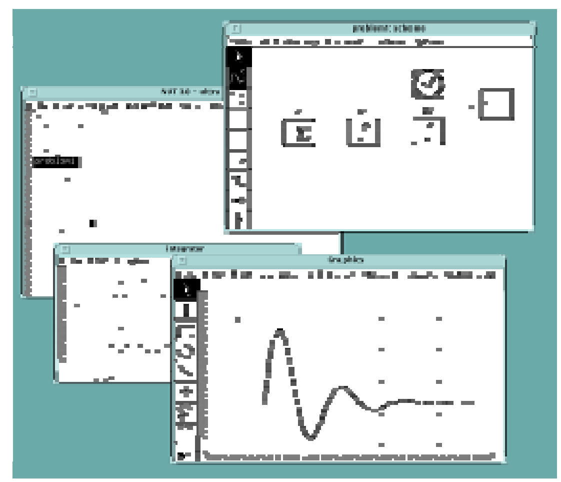
- Syntroleum fuel (Tulsa OK) very similar to Sasol isoparaffinic kerosene, used as blending component at Johannesburg Int'l airport
- Absence of aromatics leads to concerns about seals
- Sasol approved for blends up to 50% synthetic, but most experience at 30% or less

	Syntroleum F-T jet (POSF 4820)	Sasol IPK [ref: SwRI 8531]	JP-8 average (FY04 PQIS)	JP-8 spec
Paraffins (iso + normal), vol %	100	100	~60 (+~20% cycloparaffins)	
Aromatics, vol % (D1319)	0	0	17.9	<25
Specific gravity (D4052)	0.756	0.760-0.775	0.803	0.775-0.84
Flash point, C (D93)	45	42-57	49	>38
Freeze point, C (D5972)	-51	<-60	-51.5	<-47
Hydrogen content (D3343), mass %	15.4	15.06	13.84	>13.4
Heat of combustion, MJ/kg (D3338)	44.1	43.2-44.0	43.25	>42.8
Sulfur, wt%	0	0	0.05	<0.3

Step 1: Preliminary Analysis

- **Review and compare F-T fuel characteristics**
  - ☑ **South African Airlines/Air Force history**
    - **Regular commercial airlines use since 1999**
    - **Used in all SAAF aircraft/equipment**
  - ☑ **Define F-T chemical/physical properties - compare to JP-8**
    - **100% F-T fuel meets all specs <u>except</u> density (0.757 vs 0.775 min in JP-8)**
  - ☑ **Determine F-T/JP-8 blend ratios to investigate**
    - **50/50 fuel blend meets density spec**
  - ☑ **Develop F-T supportability plan (availability, blending, transportation, storage)**
    - **Current logistics practices are acceptable**

- **Exit Criteria**
  - ☑ **Determine acceptable F-T blend strategy**
  - ☑ **Successful site surveys/F-T fuel is supportable**
  - ☑ **Complies with environmental requirements**



Step 2: Small Scale Demos

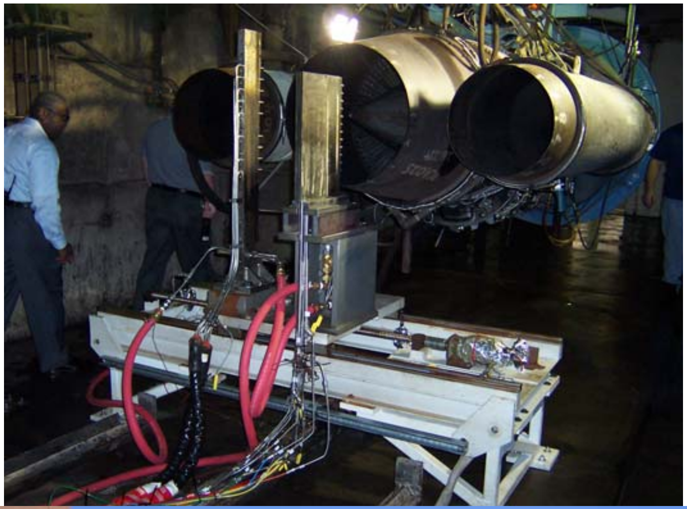
- **Off-aircraft testing and analysis**
  - **Fuel soak tests (seals, hoses, pumps, materials, etc.)**
    - ☑ **Approval granted 10 Jul to start Step 3.**
    - ☐ **Approval granted 15 Aug to start Steps 4 & 5**
  - **Small scale engine demo (T63 engine)**
    - ☑ **Acceptable engine performance and inspections**
    - ☑ **Favorable emissions data**

- **Exit Criteria**
  - ☐ **Acceptable swell rates for seals/hoses**
  - ☐ **No detrimental engine and aircraft component degradation**
  - ☑ **No detrimental small scale engine impacts identified**
  - ☑ **Successful preparation for fuels handling/storage**
  - ☑ **Determine acceptable F-T blend for ground/flight demos (= 50/50)**

T63 Turboshaft engine (250-400 SHp)

Step 3: Off-Aircraft Ground Demo

- **F-T blend used in off-aircraft ground demo**
  - ☑ **Perform TF33 engine test cell baseline and endurance run tests at Tinker AFB**
    - **Engine performance within T.O. limits**
  - ☑ **AEDC & AFRL emissions evaluations**
    - **Favorable emissions data**
  - ☐ **Conduct post-run engine inspections**



- **Exit Criteria**
  - ☑ **Acceptable engine performance within JP-8 parameters**
  - ☐ **Successful post-run engine inspection**

AFRL – 06-0078

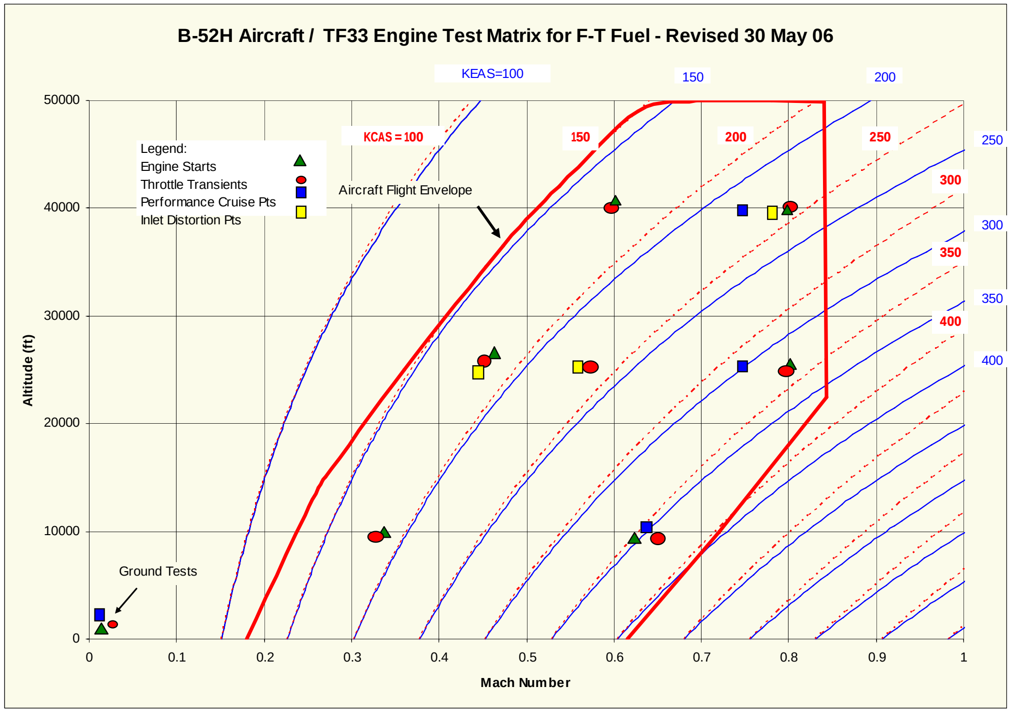
Step 4: On-Aircraft Ground Demo

- **On-aircraft thrust stand run with B-52H aircraft 60-0034**
  - **Demonstrate stability, thrust response, fuel consumption, and engine performance**
    - **Isolate 2 engines for testing with F-T blend**
    - **Compare engine operation with baseline**
    - **Limited instrumentation, but sufficient for analysis**
  - **Conduct pre and post-test maintenance inspections**

- **Exit Criteria**
  - **Acceptable engine/aircraft operation with F-T blend**
    - T.O. limits and comparable to JP-8
    - Acceptable inspection results

Step 5: Aircraft Flight Demo

- **B-52H flight demonstration**
  - **Two prior sorties for SI checkout and JP-8 baseline**
  - **Two to three sorties (10-12 hours) with F-T blend**
    - **Surface to 40K feet, approach to maximum speed**
    - **Demonstrate stability, thrust response, fuel consumption, performance**
  - **Maintenance inspections**
- **Exit Criteria**
  - **Successful on-aircraft**
    - **Within T.O. limits and**
    - **No pilot corrective**
  - **Successful post-flight engine**



Step 6: Inspections and Reporting

- **Final engine and aircraft inspections**
  - **Key engine hardware**
  - **Key aircraft hardware**
- **Final demo reporting**
  - **OC-ALC B-52 Sustainment Grou to compile results**
- **Exit Criteria**
  - **Receipt of all test reports and analysis**
  - **Consolidated report/briefing of demo results**
  - **Recommendation for next demonstration steps, qualification and certification**

Fischer Tropsch Fuel Request for Information – Purchase 200M gal

- 91 -- Request for Information - Synthetic Fuel

- Attachment 01 - Posted on May 30, 2006
- General Information

  Document Type: Sources Sought NoticeSolicitation Number:Reference-Number-DESCBCRFI001Posted Date:May 30, 2006Original Response Date:Jul 31, 2006Current Response Date:Jul 31, 2006Original Archive Date:Current Archive Date:Classification Code:91 -- Fuels, lubricants, oils & waxesNaics Code:324110 -- Petroleum Refineries
- Contracting Office Address
- Defense Logistics Agency, Logistics Operations, Defense Energy Support Center, 8725 John J. Kingman Road, Fort Belvoir, VA, 22060-6222
- Description

  - PART I: SHORT-TERM OBJECTIVE

    This is a Request for Information (RFI) only as defined in FAR 15.201(e). The Government seeks to identify responsible potential sources and obtain information regarding possible suppliers of synthetic fuel for aviation purposes that meets the Fischer-Tropsch draft synthetic fuel specification for delivery to various Air Force and Navy installations for multiple Weapon System testing and subsequent use. The Department of Defense (DoD) is investigating the feasibility of aviation synthetic fuel requirements of up to 200,000,000 U.S. gallons, or any portion thereof, for delivery during calendar year 2008, with 100,000,000 gallons meeting the JP-8 flashpoint of 38 degrees C and 100,000,000 gallons meeting the JP-5 flashpoint of 60 degrees C.

    PART II: LONG-TERM OBJECTIVE
    DoD is interested in long-term prospects for the manufacture and supply of aviation synthetic fuels in increasing quantities, with an emphasis on domestic industrial capability and feedstocks.

    PROCESS
    This request is to gather information from interested parties and is an essential step in determining market interest for the manufacture and supply of aviation synthetic fuel. In order to minimize costs both to potentially interested parties and the Government, this notice is issued to determine market interest and feasibility as well as determining market strategies for procurement of aviation synthetic fuel. Interested parties should provide a statement of interest on company letterhead. The statement of interest must not exceed a total length of 20 pages. The statement shall include, as a minimum, the following information: (1) ability to meet the draft specification (see Attachment). Comments should address specific concerns or perceived inconsistencies in the document; (2) current and future production capability (CONUS and OCONUS) on an annual basis; (3) location of production facility; (4) quantity that can be produced and when it can be made available; (5) type and location of feedstocks to be used in the production of aviation synthetic fuel; (6) capability and experience in the sale and delivery of aviation synthetic fuel; (7) distribution methods available from the production facility; (8) whether delivery can be made on a FOB destination (preferred method) or FOB origin basis; (9) financial capability to justify potential award of a supply type contract; (10) estimated start-up cost to begin production of aviation synthetic fuel (specify scale of production); (11) estimated cost, variable and fixed, of producing a gallon of fuel; (12) understanding of Federal, state, and local environmental laws and regulations, and familiarity and experience with environmental compliance procedures and regulations for applicable states and U.S. Environmental Protection Agency Regions; and (13) company point of contact, telephone number, and email address.

    In addition, interested parties should provide comments on the nature and level of Federal and State incentives and/or obligations (e.g., R&D, capital investment, investment or production incentives) needed to develop and sustain long-term domestic commitments to produce aviation synthetic fuels.

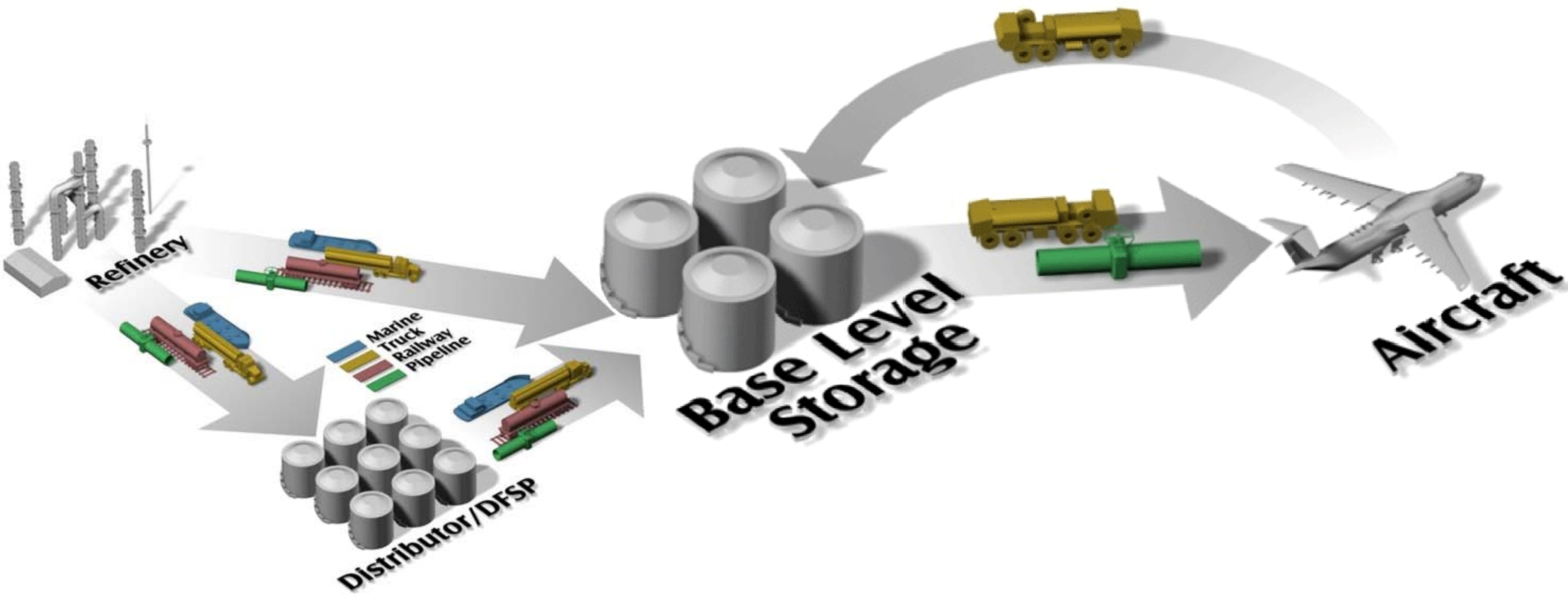
    DISCLAIMER
    This RFI is issued solely for information and planning purposes and does not constitute a solicitation. All information received in response to this RFI that is marked Proprietary will be handled accordingly. Responses to the RFI will not be returned. In accordance with FAR 15.201(e), responses to this notice are not offers and cannot be accepted by the Government to form a binding contract. Responders are solely responsible for all expenses associated with responding to this RFI.

    CONTACT INFORMATION
    Emma Smith, Contract Specialist, Phone 703-767-9253, Email Emma.Smith@dla.mil
    Phyllis Orange, Contracting Officer/Division Chief, Phone 703-767-9305, Email Phyllis.Orange@dla.mil

    HOW TO RESPOND
    Please submit comments no later than July 31, 2006. Preferred media is electronic copies in Microsoft Word, Power Point, or Excel. Preferred method of submission is via email.

- Point of Contact
- Emma Smith, Contract Specialist, Phone 703 767-9253, Fax 703 767-9269, Email Emma.Smith@dla.mil - Phyllis Orange, Contract Specialist, Phone 703 767-9266, Fax 703 767-9269, Email phyllis. orange@dla.mil

Define all Elements of the Enterprise



Capabilities

Hundreds of MDS

Thousands of Ground Support & Vehicles

Multiple Value Chains

Base

Environmental

Health & Safety

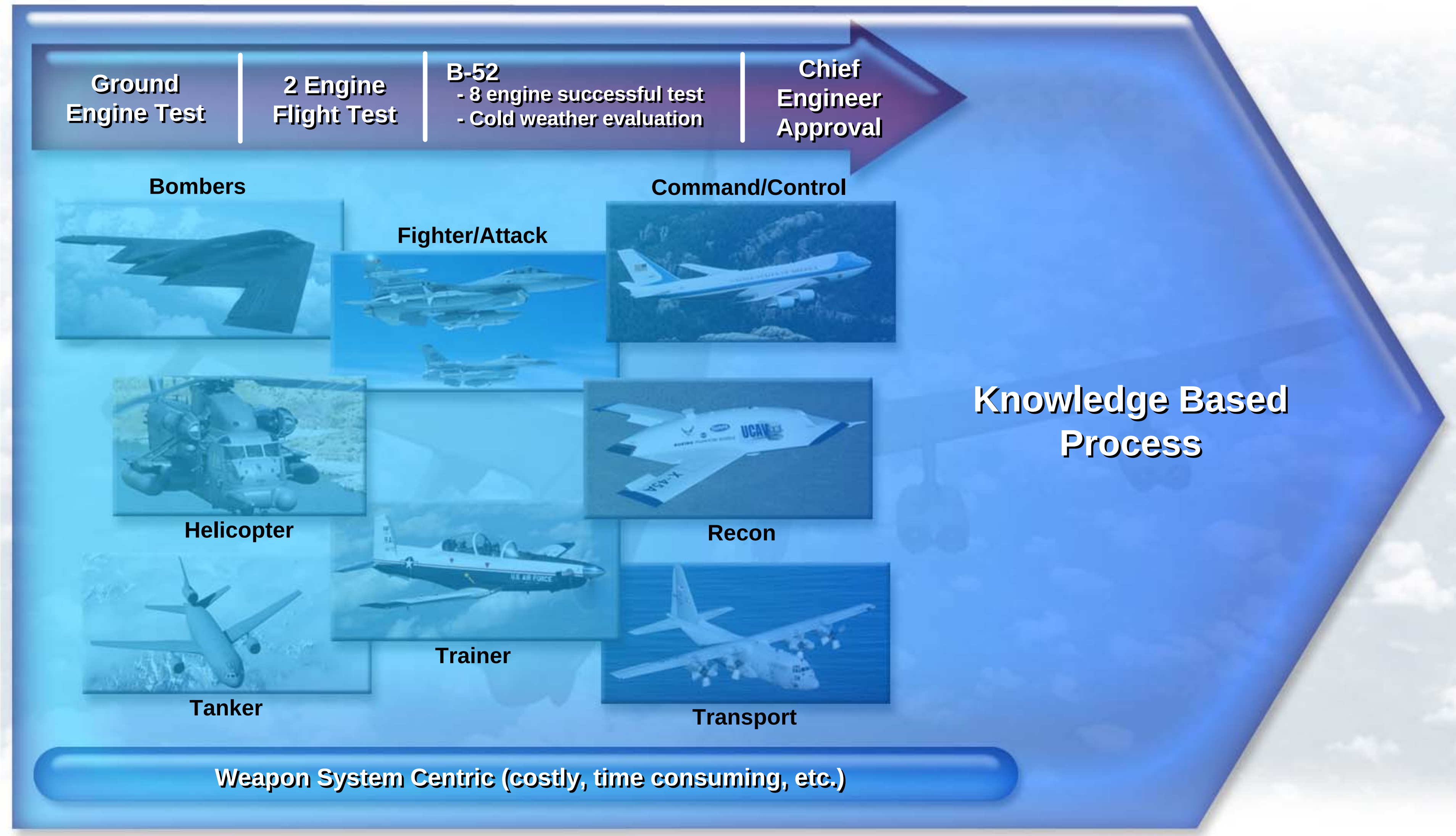
Personnel & Training

Infrastructure

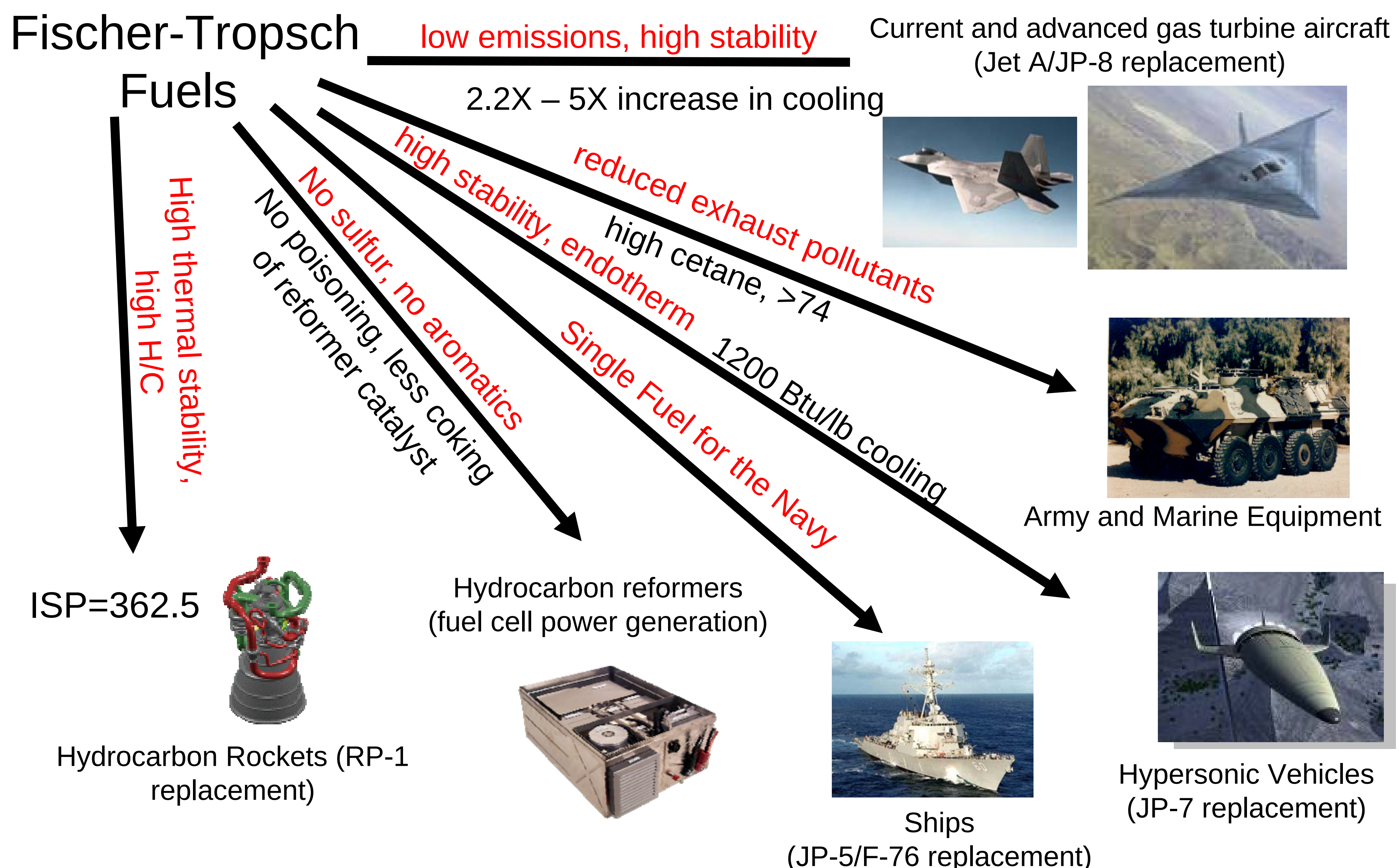
Similar Components

Lean Process

Lean Knowledge Based Process



SINGLE BATTLESPACE FUEL
From Unconventional Resources



AFRL – 06-0078

Summary

- US Air Force is serious about using synthetic fuel blends (near term)
  - B-52 Flight Demo by end of Summer
  - Future demonstrations are being investigated
  - Potential 100M gal purchase in 2008/09
  - Establish certification process
- Ongoing research into the development & use of fully synthetic fuel (far term)
  - Assess operability/durability impacts
  - Understand role of aromatics and materials
  - Maximizes benefits of synthetic jet fuel
  - Develop S&T tech base for Single Battlespace Fuel
- Advance high heat sink fuels enable Improved fuel efficiency in advanced designs