NAVSEA
NAVAL SEA SYSTEMS COMMAND
SEA 05
Naval Systems Engineering Directorate

Alternative Fuels Qualification and Testing

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Surface Navy Symposium
11 January 2012

Navy Energy Goals

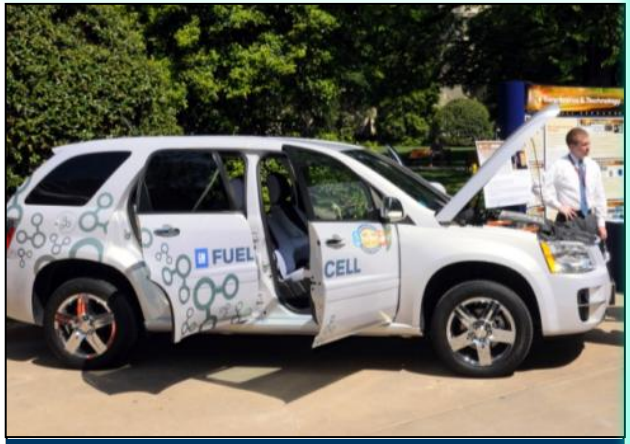
50% Alternative Energy by 2020

Sail the Great Green Fleet

2012 Green Strike Group Demo

2016 Great Green Fleet Sail

50% Net Zero Installations by 2020



50% Less Petroleum in Commercial Vehicles by 2015

Energy Efficient Acquisition

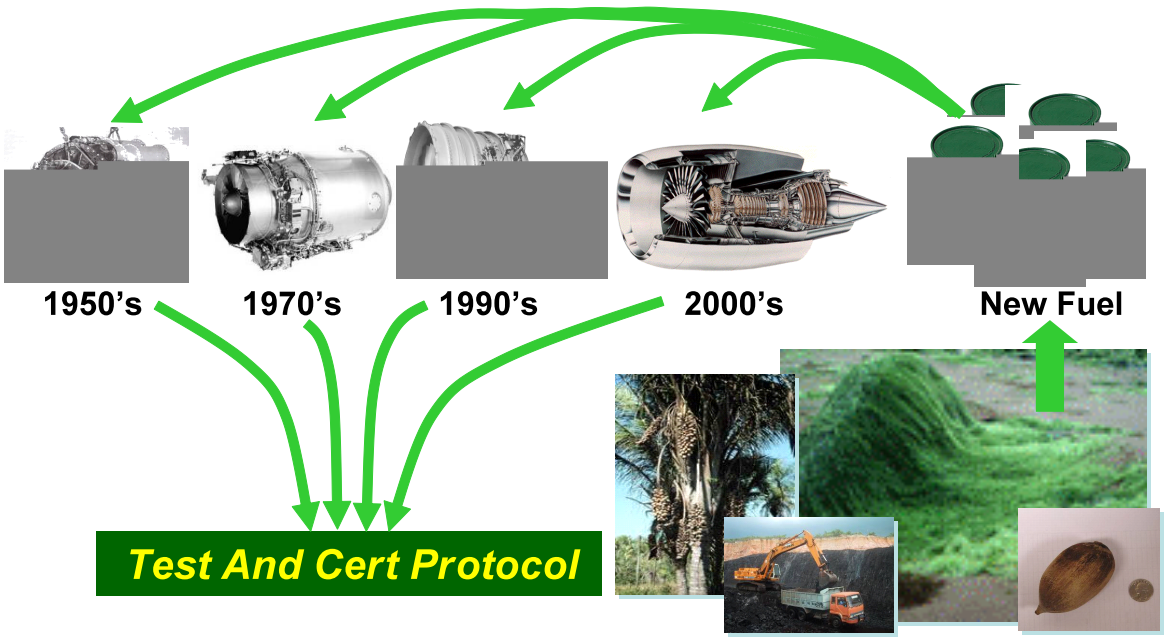
Alternative Fuels Strategy

Primary Assumption:
Alternative fuel must be a drop-in replacement, invisible to the operator

- ✓Meets fuel performance requirements
- ✓Can be mixed or alternated with petroleum fuel
- ✓Requires NO change to aircraft or ship
- ✓Requires NO change to infrastructure

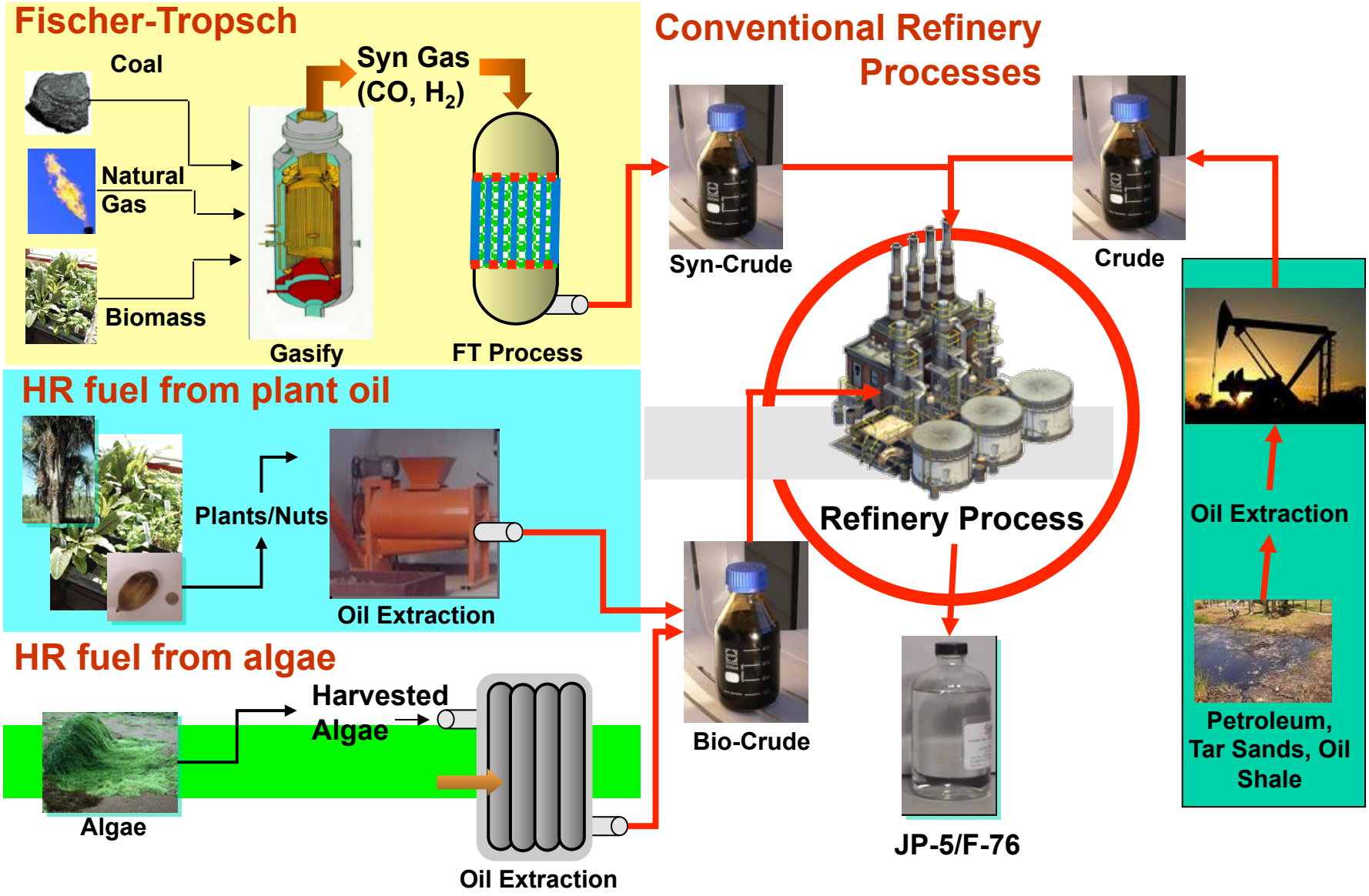
Challenge:

Existing Systems

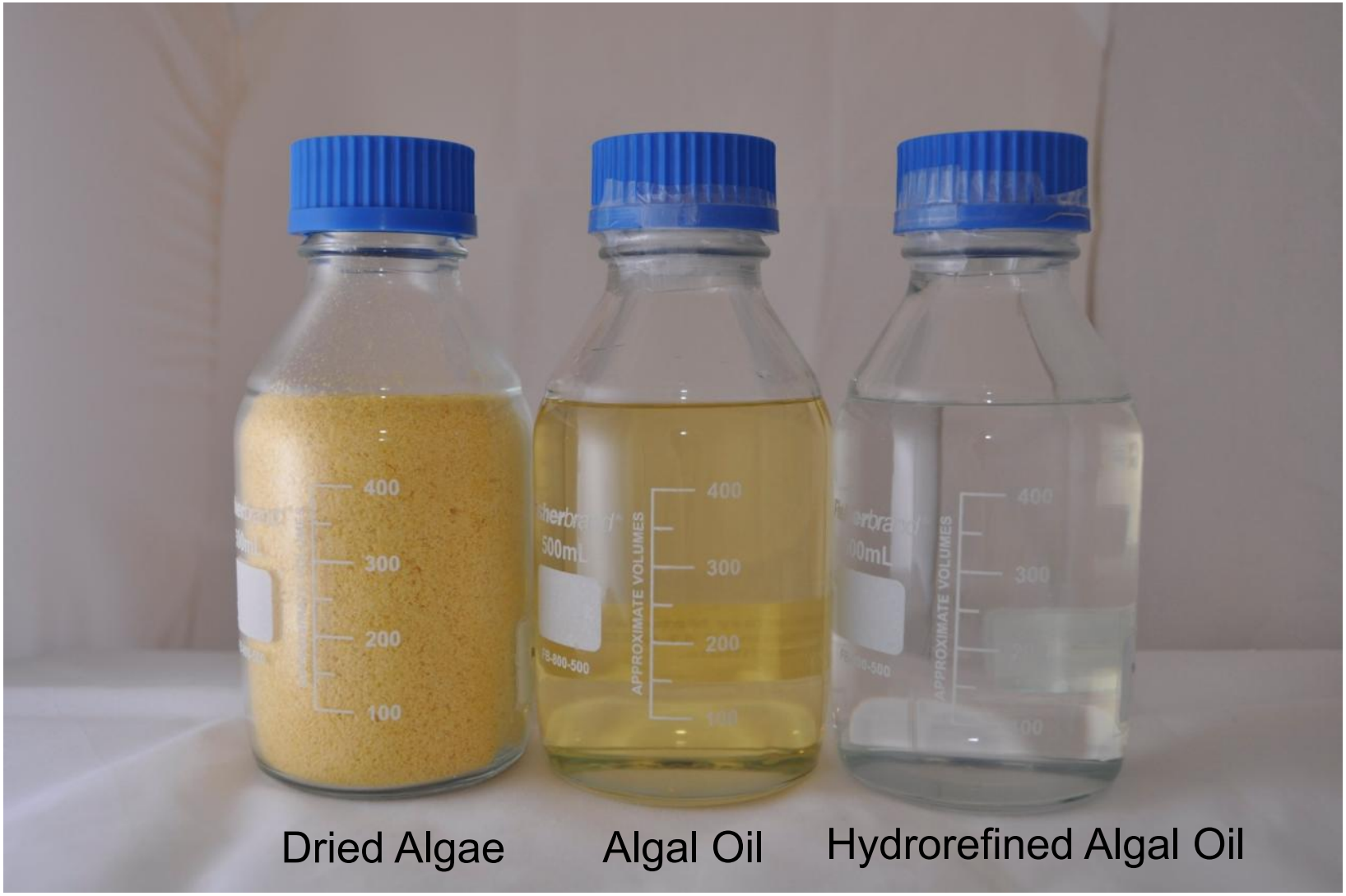


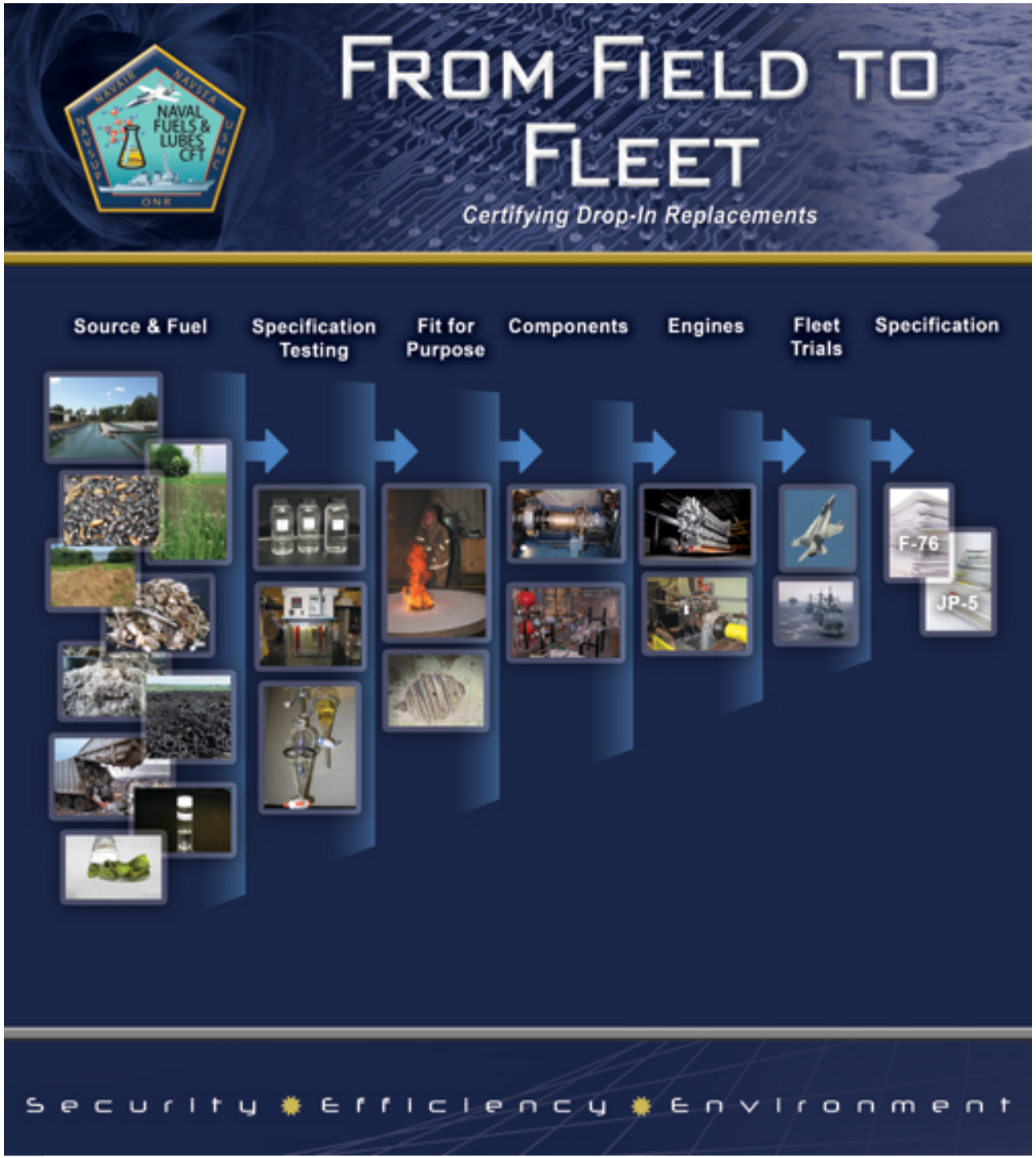
Not Changing the Fuel : Just its Source

Potential Alternative Sources for F-76 and JP-5



Shipboard Alternative Fuel





Phase 1: Evaluating chemical and physical properties:

Specification

Fit-for-Purpose

Phase 2: Validating hardware performance:

Components

Engines

Phase 3: Operational Trial

Phase 4: Inclusion into F-76 (Ship) Specs or JP-5 (Aircraft)

DLA Energy Procures For Use

50/50 Blend of HRD76 & Petroleum F-76 Specification Test Results

Characteristic	MIL-DTL-16884L Requirements	Petroleum F-76 (typical)	50/50 Blend (actual)
Acid Number (mg KOH/g)	0.30 (max)	0.08	<0.05
Appearance	Clear & Bright	C & B	C & B
Ash (wt%)	0.005 (max)	<0.001	<0.001
Carbon Residue, (10% bottoms) (wt%)	0.20 (max)	0.07	0.09
Cloud Point (°C)	-1 (max)	-5	-11
Color	3 (max)	1	<2.5
Corrosion @ 100°C	1 (max)	1a	1a
Demulsification @ 25C (minutes)	10 (max)	3	2
Density @ 15°C (kg/m3)	800 – 876	845	806
Distillation (°C) - IBP	Record	180	189
10% Point	Record	218	205
50% Point	Record	282	263
90% Point	357 (max)	338	300
End Point	385 (max)	364	330
Residue + Loss (vol%)	3.0.(max)	2.0	1.8
Flash Point (°C)	60 (min)	65	65
Cetane Number	42 (min)	51	59
Hydrogen Content (wt%)	12.5 (min)	13.3	14.0
Particulate Contamination (mg/L)	10 (max)	2	2
Pour Point (°C)	-6 (max)	-11	-18
Storage Stab.(16) hrs	3.0 mg/100ml (max)	0.7	<0.1
Sulfur (wt%)	0.5 (max)	0.3	0.06
Trace Metals: Ca (ppm)	1.0 (max)	<0.1	<0.1
Trace Metals: Pb (ppm)	0.5 (max)	<0.1	<0.1
Trace Metals: Na+K (ppm)	1.0 (max)	<0.1	<0.1
Trace Metals: V (ppm)	0.5 (max)	<0.1	<0.1
Viscosity @ 40°C (mm2/sec)	1.7 - 4.3	3.3	2.3

50-50 blend of HRD76 and petroleum F-76 meets MILSPEC requirements

Fit-for-Purpose Properties

Bulk Physical and Chemical Properties

- Aromatics
- Bulk Modulus vs. Temp.
- Density vs. Temperature
- Electrical Conductivity
- Existent Peroxides
- Heating Value
- Hydrocarbon Composition Analysis
- Microbial Growth
- Thermal Cond. vs. Temp.
- Trace Metals
- Specific Heat vs. Temperature
- Viscosity vs. Temperature

Performance

- Cetane Number, Derived
- Combustion Characteristics
- Distillation
- Filtration Time
- Interfacial Tension
- Lubricity
- Navy Coalescence Test
- Thermal Stability
- Smoke Point
- Storage Stability (Peroxides)
- Surface Tension
- Water Solubility

Compatibility

- Fuel and Additives Compatibility
- Lube Oil Compatibility
- Materials, Turbine Hot Section
- Materials, Metallic
- Materials, Non-Metallic

Fire/Safety/Survivability/Environmental

- Autoignition Temperature
- Fire Safety Test
- Hot Surface Ignition Temperature
- Off-gassing
- Oil Pollution Abatement
- Shielding
- Toxicity

Component & Full-Scale Diesel Engine Testing

Selected Engine Makes/Models	Component
• Caterpillar 3500 • Colt Pielstick PA-6 • Cummins QSB • Fairbanks Morse 38D 8-1/8 • Lucas Bryce (Paxman Valenta) • MTU 396 • Yanmar L • EMD 645[1]	Fuel Injectors

[1] EMD 645 and Colt Pielstick PA-6 will be tested with alternate JP-5 blend

Selected Engine Makes/Models	Test Method	Acceptance Criteria
• Caterpillar 3500 • Cummins QSB[2] • Fairbanks Morse 38D 8 1/-8 • MTU 396 • Colt Pielstick PA-6 • EMD 645[3]	Modified 96-hour endurance, performance, emissions, full-scale dynamometer engine test	Derived from acceptance criteria specified in ABS NVR (Diesel Engines "Testing, Inspection and Certification Requirements")

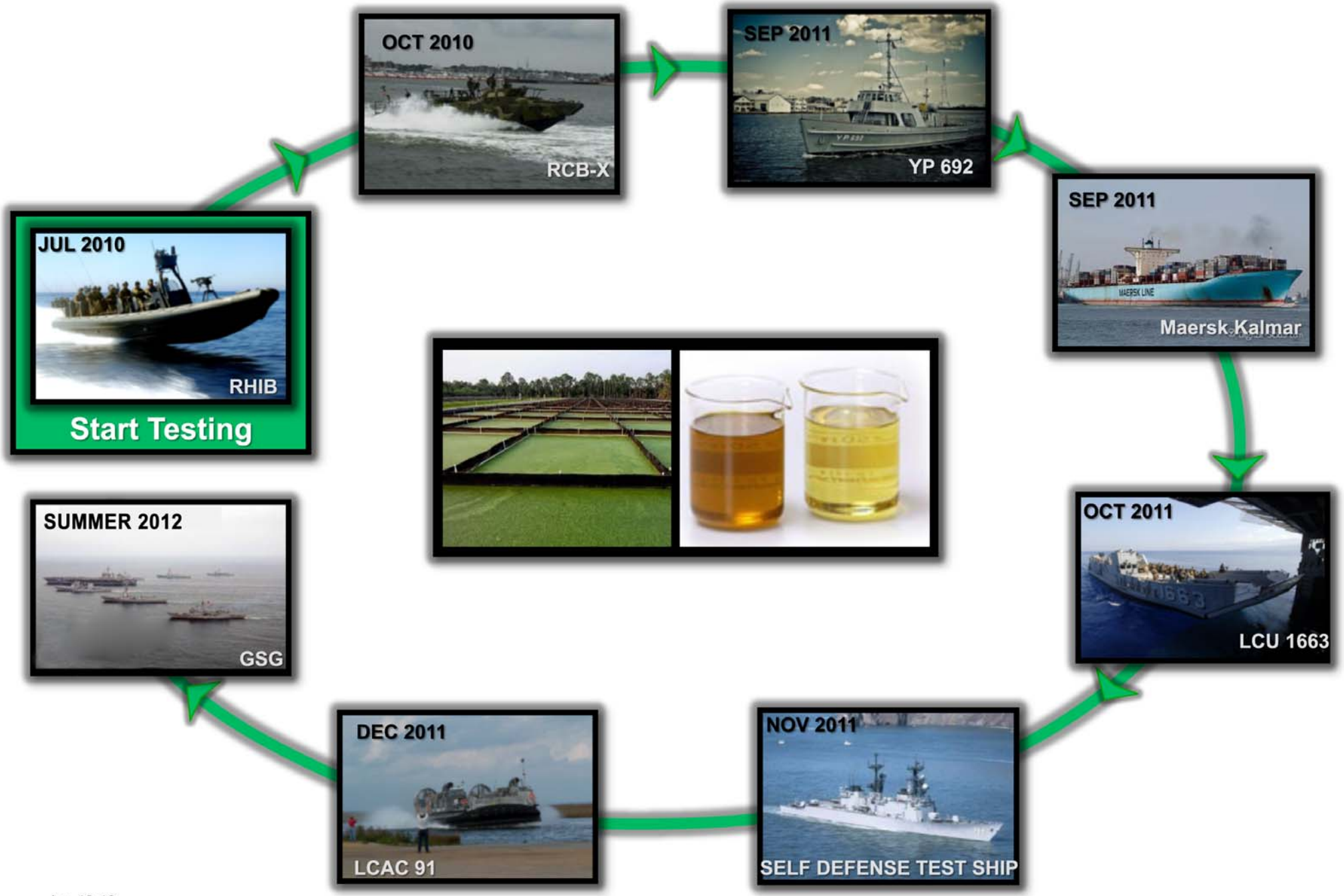
[2] Cummins QSB will be tested for 250 hours
[3] EMD 645)and Colt Pielstick PA-6 will be tested using a full scale engine protocol with JP-5 instead of F-76

Component & Full Scale Gas Turbine Testing

Components (Nozzles and Rigs are 501-K34 design)	**Test**	**Test Rig**
Fuel Nozzles	Atomization & Spray Pattern	Fuel Nozzle
Fuel Nozzles	Fouling/Coking	Hot Fuel Nozzle
Combustion & Ignition Systems	Ignition/Stability (light-off, lean blowout)	501-K34 Single Burner Combustor
Fuel Nozzles	Carbon Deposition	501-K34 Single Burner
Combustor/Nozzles	GT Performance (combustor efficiency, emissions, smoke, flame radiation, exit pattern factor, liner temps)	501-K34 Single Burner

Test Engine	**Test**
Rolls Royce 501-K34	NVR Type B3 CAT IV Endurance Test. (Modified 43.5-hour endurance, durability, performance, emissions, full-scale engine test)

Navy Maritime Alternate Fuel At-Sea Demo Plan



7m RHIB Demonstration

- **7m RHIB operated on 50-50 blend of hydrorefined algal oil and petroleum F-76 at Fort Monroe in July 2010**
- **Operated on petroleum F-76 as a baseline to compare performance**
  - **No discernable differences in craft performance or behavior were observed**
    - Craft speed, horsepower, fuel consumption, shaft torque
  - **Operated on a range of engine speeds from 600 rpm to full power (>3000 rpm)**

Riverine Command Boat Demonstration

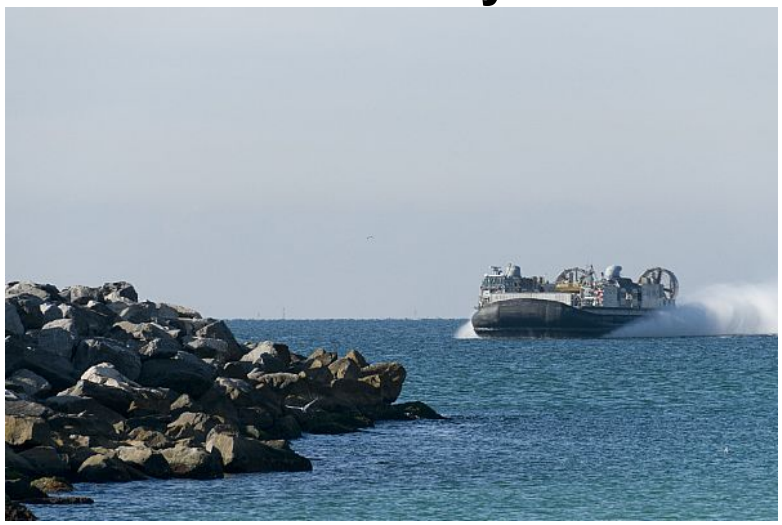
- **Riverine Command Boat (RCB-X) operating on a 50-50 blend of hydrorefined algal oil and petroleum F-76 on 19 October 2010**
- **No difference in operation between the fuel blend and F-76.**
- **Public demonstration of RCB-X operating on fuel blend took place at NOB on 22 October 2010.**

Self Defense Test Ship Demonstration

- **Self Defense Test Ship (SDTS, Ex DD 964) operating on a 50-50 blend of hydrorefined algal oil and petroleum F-76 on 17 November 2011 on a transit from San Diego to Port Hueneme.**
- **One GTM (LM2500) and one GTG (501-K17)**
- **No difference in operation between the fuel blend and F-76.**

LCAC Demonstration

- **Landing Craft Air Cushion (LCAC 91) operating on a 50-50 blend of hydrorefined algal oil and petroleum F-76 was completed on 7 December 2011**
- **No difference in operation and performance while achieving the fastest US Navy surface craft speed (50 knots) using alternative fuel.**
- **A public demonstration operating on fuel blend took place at NSWC Panama City on 9 December 2011.**



Summary - Navy's Alternative Fuels Qualification Approach

Maritime

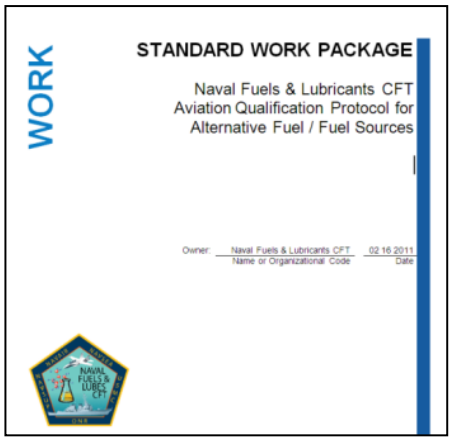
Requirements

Testing

Specification Modification

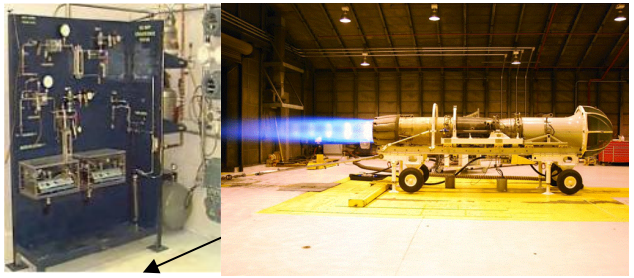
MIL-DTL-16884
F-76 Spec

Aviation



Requirements

Testing



Specification Modification

MIL-DTL-5624
JP-5 Spec