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ALTERNATIVE FUELS

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Report Documentation Page

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Topics

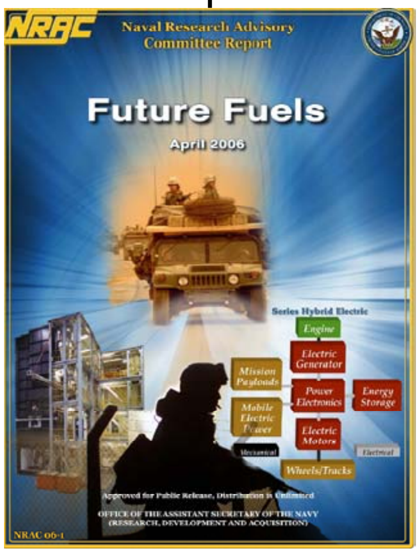
- **Introduction**
  - Transportation Market Evolution
  - Tactical Mobility Fuel
- **Single Fuel in the Battlefield**
  - What is the Single Fuel?
  - Certification / Qualification Pipeline
  - DARPA Alternative Jet Fuels Program
- **Coordinating the Overall Alternative Fuel Qualification Process**
  - Tri-Service POL Users Group
  - Within Army
- **Alternative Fuels Qualification – Status**
- **Army Fuel Requirements and the JP-8 Spec**

Transportation Market Evolution

21st Century
Transportation market evolution continues, shaped by heightened concerns about energy security and the environment.

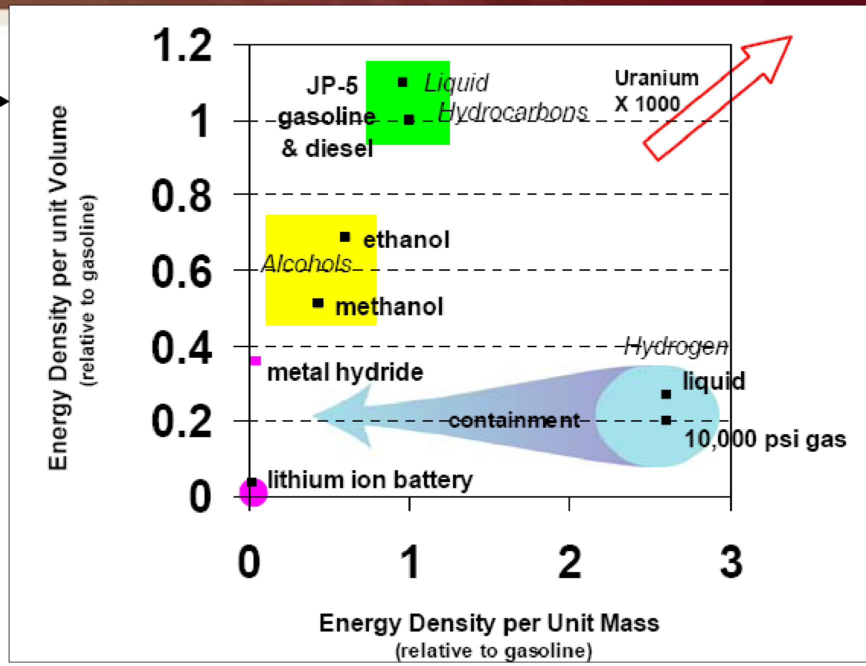
- **Alternative fuels desired in the jet/diesel fuel supply**
- **Changes in fuels supply driven by**
  - Legislation [EPAct 2005, EISA 2007], Exec Orders [EO 13423]
  - USAF Alternative Jet Fuels Program with goal to certify aircraft on alternative jet fuels by 2011
  - Commercial Aviation Alternative Fuels Initiative (CAAFI)
  - Various initiatives to manufacture alternative fuels from diverse sources
- **Army active in assessing emerging changes**
  - Tri-department coordination of alternative fuels qualification efforts

Tactical Mobility Fuel



Naval Research Advisory Committee Panel* Report (April 2006)

* Dr. Walt Bryzik panel member, Chief Scientist, (Ret) TARDEC



Liquid hydrocarbons – ideal fuel for tactical mobility

DOD SINGLE FUEL POLICY

AVIATION KEROSENE GRADE (JP-8)

MIL-DTL-83133

JP-8 (Jet A-1 plus additives) is the primary fuel used for both air and ground equipment in all theaters, overseas and Continental U.S.

- **Tactical vehicle** designs impose severe limitations on volume and weight
- **Energy density** is therefore the primary consideration for fuel
- **Hydrogen presently unsuitable** as a tactical mobility fuel
  - – made from other fuels/resources
  - – containment reduces energy density by 10-20X

What is the Single Fuel?

Biomass Energy (renewable)

Fossil Energy (large U.S. resource)

Petroleum Crude Oil (declining discovery / production)

Diverse energy sources

Petroleum based

Non-Petroleum based

Single Fuel in the Battlefield (SFB)*: Kerosene-type (jet) fuels, whether petroleum-based or not, allowed under specs for JP-8 / JP-5 / Jet A-1

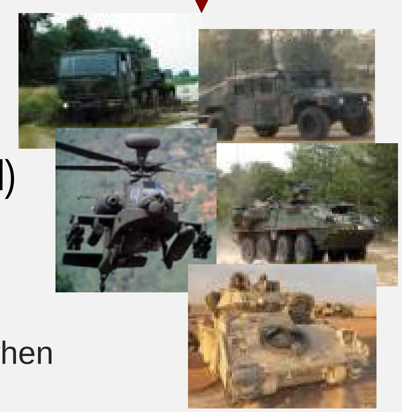
Alternative jet, diesel fuels

- Produced for dual-use (military and commercial)
- Meet specs used by military
- Often blends with petroleum-based fuels

* SFB Policy allows diesel fuel in ground equipment when supplying jet fuel not practicable or cost effective

Alternative Fuels RDT&E:

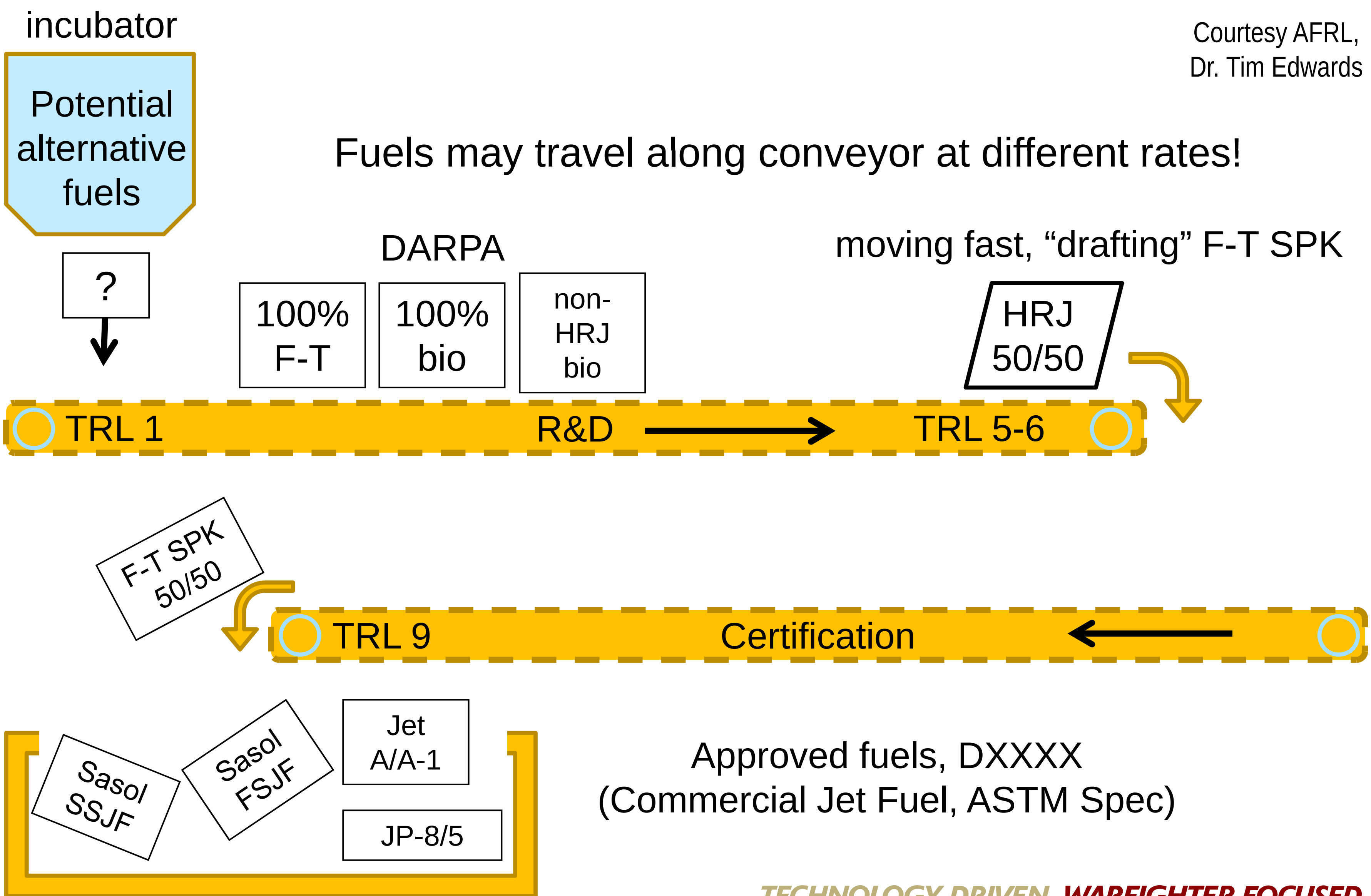
- Expand technical database on alternative fuels
- Engage in specifications development for alternative fuels
- Qualify alternative fuels for use in Army tactical / combat equipment and systems



TARDEC Alternative Fuels Focus

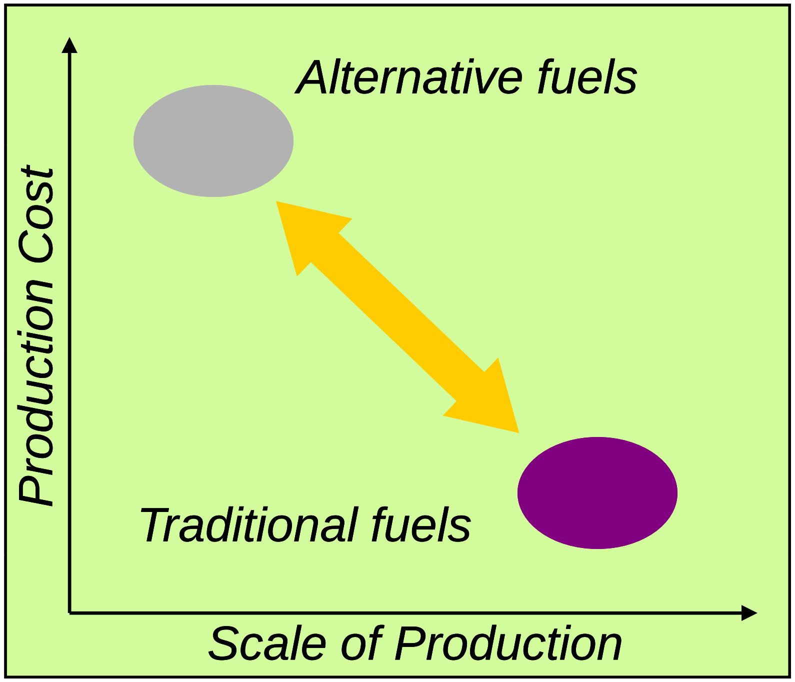
Certification / Qualification Pipeline

Courtesy AFRL,
Dr. Tim Edwards



DARPA Alternative Jet Fuels

- **Agricultural crop oils** (canola, jatropha, soy, palm, etc.)
  - University of North Dakota EERC
  - UOP
  - General Electric (GE)
  - Swedish Biofuels AB
- **Cellulosic and algal feedstocks** that are non-competitive with food material
  - General Atomics ($19.9M)
  - SAIC ($25M)
- Acceptable **coal-derived** fuels
  - $8.4M total
  - proposals due 02 Jun 2009



Can alternative jet fuels be made on large-scale and be cost competitive?

Coordinating Overall Process for Alternative Fuel Qualification

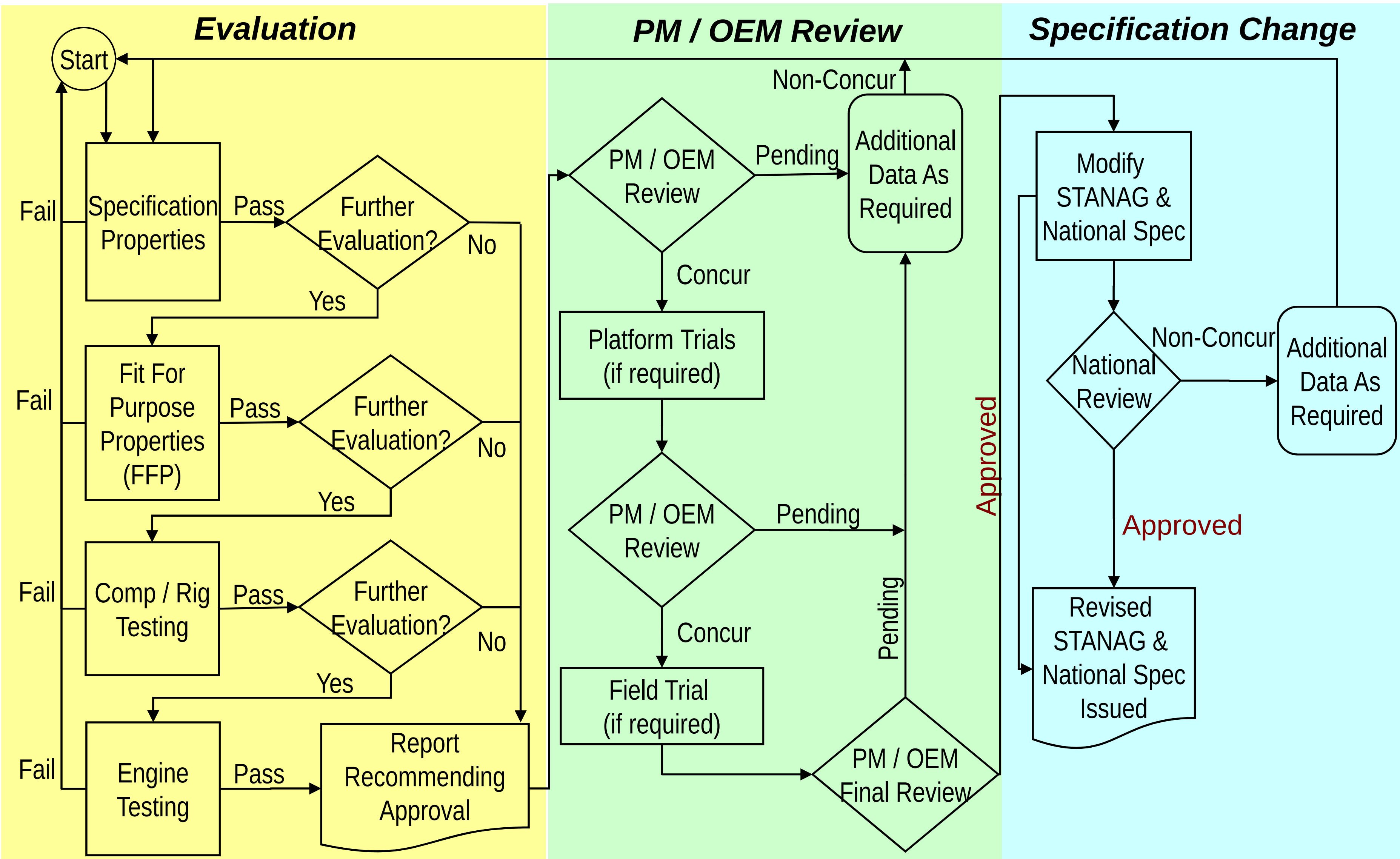
- **Tri-Service POL Users Group**
  - Developing DoD qualification process
    - Includes all stakeholders (e.g., aircraft, ground vehicles/GSE, infrastructure . . .), OEMs
    - Process specified and mandated for alt fuel producers independent of feedstock
    - Requires process be recognized by major fuel specifications, standard agreements

  FY08 Focus:
  - Synthetic fuels database populated (85%)
  - JP-8 specification FT wording coordinated
  - Continued liaison with DESC SynFuels Working Group
  - Shared Lessons Learned, data and resources

  FY09 Challenges:
  - Conduct gap analysis – synfuel efforts, expand to biofuels, ID potential joint efforts
  - Increase visibility outside SCP world
  - More awareness needed that group exists, recognition as key OSD asset
  - Development of framework for DoD test and certification process
- **Within Army**
  - Currently in evaluation phase (see process flow chart next slide)
  - Coordination with AMRDEC, need to expand to other key RDEC stakeholders

Alternative Fuel Evaluation & Approval (Notional Qualification Process)

RDECOM TARDEC



Army Synfuel Blends* Qualification Process

← Develop data needed to assess fuel's suitability for use. → ← Build user knowledge of and confidence in use of fuel. →

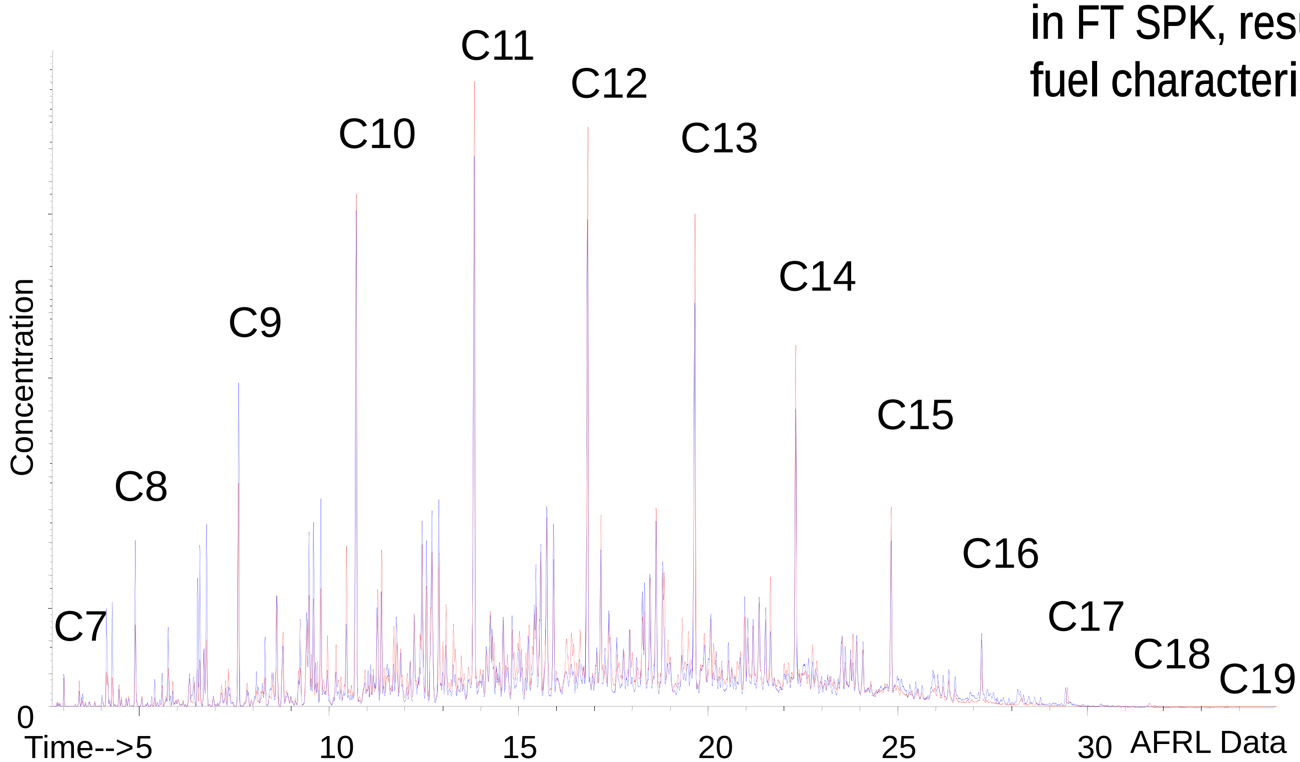
Laboratory Evaluations → Component Evaluations → System Evaluations → Demonstrations

- **Completed**
  - Fuel chemical composition and properties
  - Materials compatibility evaluations
  - Fuel lubricity evaluations (rotary fuel injection pump)
  - Fuel blends studies
  - Limited component/engine/system testing (ground equipment)
- **In Progress**
  - Engine performance / durability testing (NATO test cycle)
  - Test track evaluation – HMMWV
  - Tactical wheeled vehicle (5x5) pilot field demo
  - Fuel lubricity evaluations (common rail injection system)
  - Cetane - Volatility window studies
- **Planned**
  - Component/engine/system testing and demos **(Army Aviation)**

* Synfuel Blends: blends of Fischer-Tropsch Synthetic Paraffinic Kerosene and JP-8 meeting MIL-DTL-83133F(JP-8 spec)

Properties of Synthetic Paraffinic Kerosene (SPK)

JP-8
Fischer-Tropsch (FT) SPK*



- Nothing in FT SPK that is not in JP-8
- Not all compounds in JP-8 are necessarily in FT SPK, results in some differences in fuel characteristics

Aromatics:
Lower fuel density and volumetric energy density, higher Cetane No., less solvency

Sulfur:
No exhaust SOx

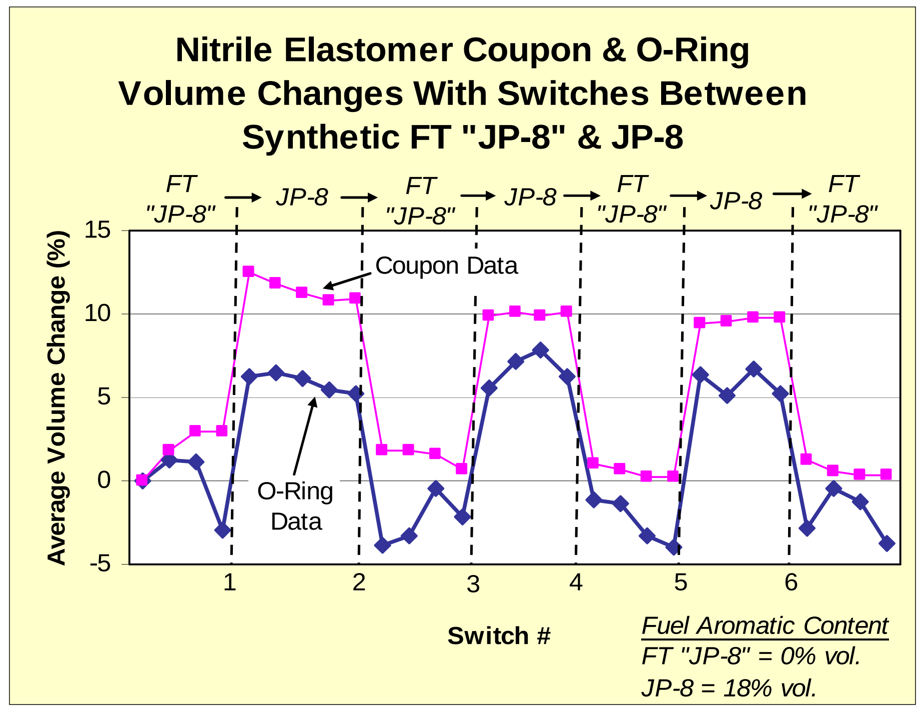
Trace compounds:
Less inherent fuel lubricity

- Can impact component or engine performance and durability

*Synthetic-Paraffinic Kerosene:
Hydrocarbons distributed across the full jet fuel boiling range and having on whole properties suitable for use as an aviation fuel.

Fuel Blends Are Implementation Path

- **TARDEC elastomer compatibility evaluations* supported a "blends implementation path"**
- **Blends of up to 50% by volume FT SPK with JP-8**
  - Blends minimize/eliminate risk of fuel leaks due to change in fuel aromatic content
- **Other aspects supporting a blends implementation path**
  - Production capacity will build slowly
  - Lower energy density of FT SPK



- Nitrile components swell in JP-8, then shrink when switched into FT SPK (FT "JP-8")
- O-ring shrinkage increases risk of sealing failures
- Using unaffected o-ring elastomers or FT SPK in blends with JP-8 are ways to reduce this risk

***SAE Paper 2007-01-1453**

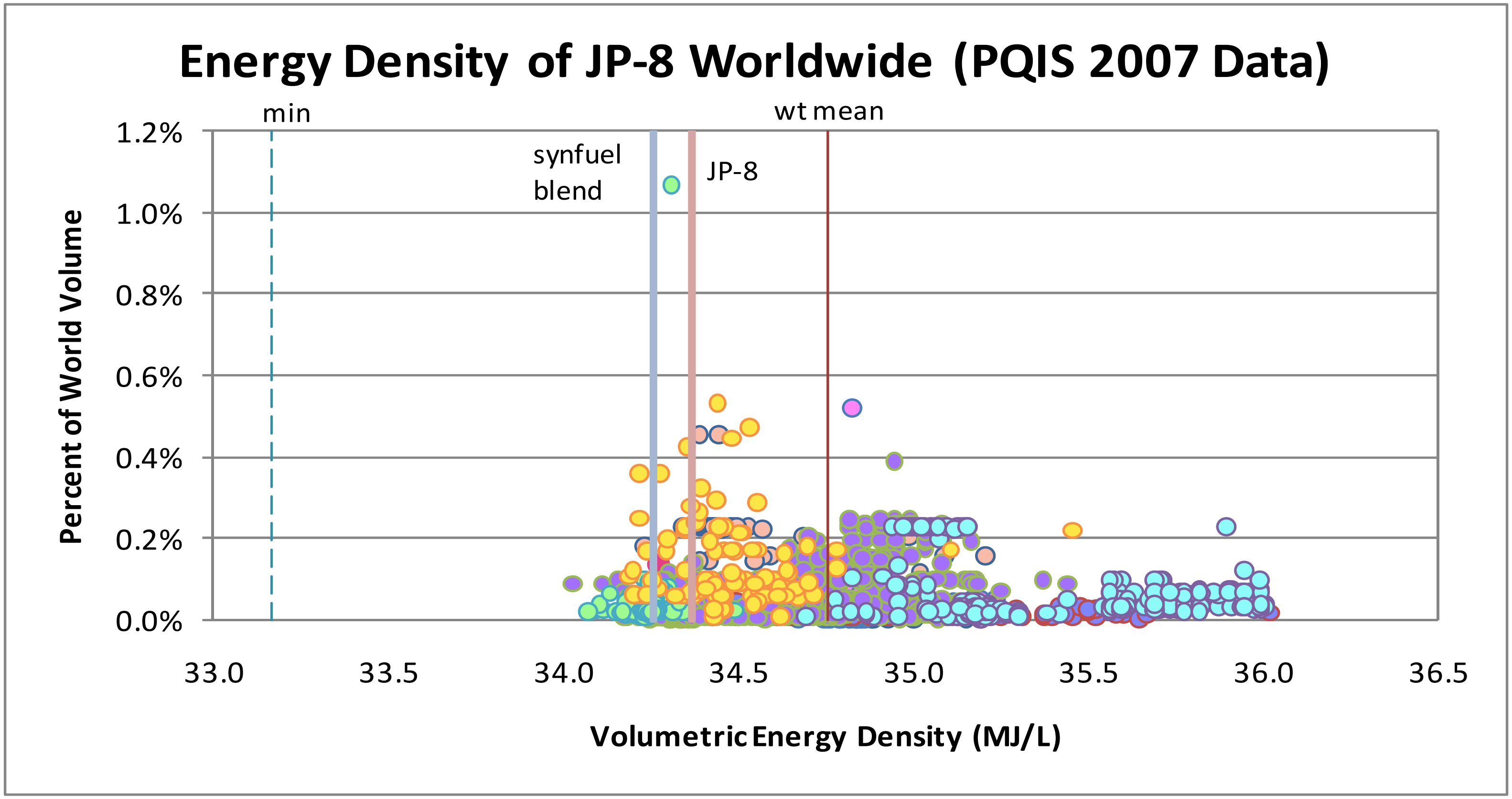
Blends Study

- **FT SPK/JP-8 Blend Properties**
  - Compared properties of blends with typical properties of JP-8 (CONUS, 2004)
  - Determined properties of blends (up to 50% FT SPK) generally fell within typical "property box" of JP-8
  - Study documented in **SAE Paper 2006-01-0702**
- **Follow-on study looked at typical JP-8 in use at five Army installations in CONUS**
  - Determined that at four of the five installations blends with the maximum reduction of 50% by volume petroleum content (JP-8) are possible
  - Study results documented in **2007 IASH Conference Poster** (see next slide)
    - International Association of the Stability, Handling and Use of Liquid Fuels (IASH)

Property Values of Synfuel Blends* Fit Within Range for JP-8

EXAMPLE: Volumetric Energy Density (see chart)

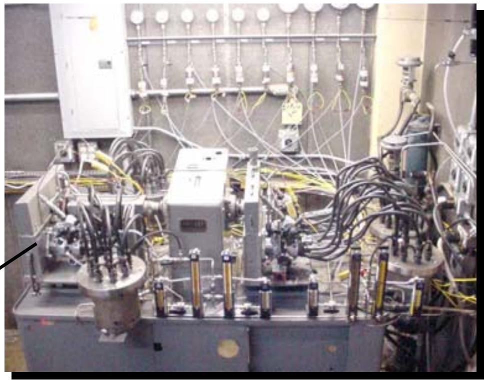
- **(1) JP-8 batches procured in 2007 worldwide, range and distribution, wt. mean.****
- **(2) Test fuels, GEP engine evaluation. JP-8 and synfuel blend**
- **(3) Minimum shown is calculated from what is allowed by JP-8 spec. for minimum density and minimum net heat of combustion.**



* Synfuel Blends: blends of Fischer-Tropsch Synthetic Paraffinic Kerosene and JP-8 meeting MIL-DTL-83133F(JP-8 spec)
** Calculated values; batches missing data not included

Lubricity Testing
TARDEC F&L Research Facility

- **Bench-top lubricity evaluations**
  - BOCLE, SLBOCLE, and HFRR battery
  - BOCLE indicated improved lubricity of FT fuel treated with CI/LI additive per QPL-25107



- **Rotary fuel injection pump test rig testing**
  - Showed FT IPK with lubricity improved to a level indicative of acceptable field performance
  - Both at min. and max. treat rates per QPL-25017
  - Results documented in **SAE Paper 2004-01-2961**

“Early Demo” – Tactical Generators
TARDEC F&L Research Facility

- **Objective:** Operate tactical equipment using 50:50 FT synthetic fuel blend
- **Test Protocol**
  - – Three 10 kW generator sets
  - – Gen sets “broken-in” using Ultra-Low Sulfur Diesel (ULSD)
  - – Gen sets fueling during test, operating cycles (% of total time)
    - Gen sets #1 & # 3
      - ➢ 10% – ULSD
      - ➢ 45% – JP-8
      - ➢ 45% – 50:50 blend of FT SPK:JP-8
    - Gen set # 2
      - ➢ 100% – FT SPK
  - – Tests conducted for 1000 hrs at 50% load
- **Some Results** (final report in DTIC)
  - – No reliability issues encountered
  - – Power generation unchanged for all fuel cases
  - – Exhaust emission checked; NOx lower using fuel blend than for JP-8

TWV Pilot Field Demo
TARDEC F&L Research Facility

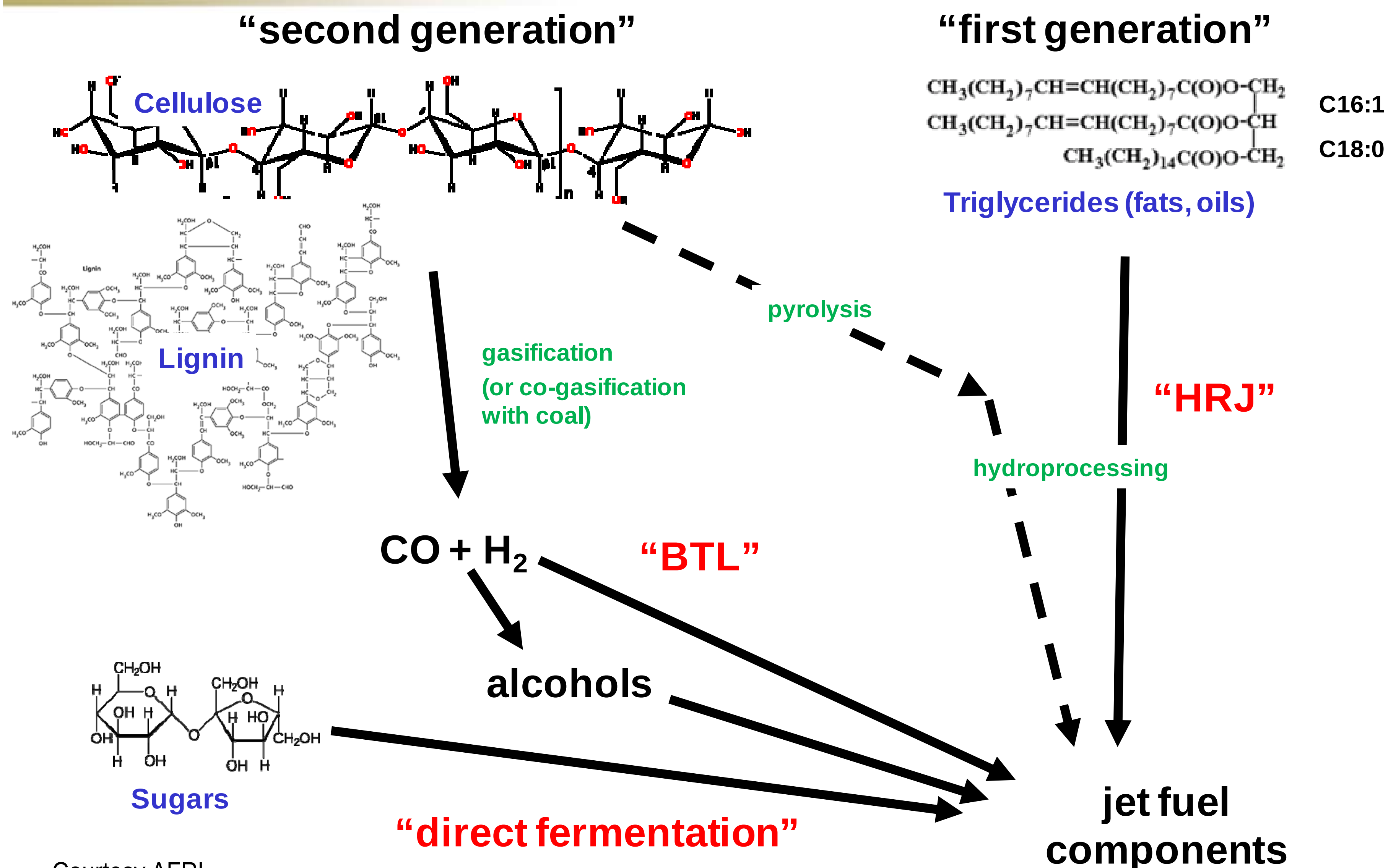
- **Determine effects of using fuel blend in a subset Army legacy ground vehicles**
- **Field demonstration fleet (variety of wheeled vehicles) at Ft. Bliss, TX**
  - (2) M998 HMMWV
  - (9) M925 A2 5-Ton truck
  - (10) M1075 LMTV
  - (10) M1083 A1 FMTV
  - (2) M1089 A1 FMTV
  - (1) M984 A1 HEMTT
  - (1) M978 HEMTT
  - (10) M915 A4 TRAC
  - Control vehicles of the same type, operated on JP-8 will be included
- **Data generation**
  - Monthly fleet performance monitoring and fuel analyses
  - Vehicle fuel injection systems pre-test inspections for operation / fuel leaks
  - Up to 10 fuel injection system (blend fueled vehicles) post-test inspections (or earlier if needed) to check operation / fuel leaks
- **No recordable issues to-date**
- **Field demo expected to finish in July 2009**

Army Fuel Requirements and the JP-8 Specification

- **Army started conversion from diesel fuel to Single Fuel in the Battlefield (SFB) in 1980s, implemented in 1988**
  - Done on “no-harm” premise basis for use of aviation turbine engine fuel in Army equipment typically having compression ignition (CI) engines
- **Army equipment has generally maintained acceptable levels of performance and durability using SFB, but have been some issues**
- **Requirements in diesel fuel specs not in JP-8 spec**
  - Minimum viscosity at 40°C (1.3 mm^2/s, No. 1-D)
    - Low fuel viscosity could lead to increased wear rates in some types of fuel injectors and injection pumps
  - Minimum Cetane No. (40, No. 1-D and 2-D)
    - Better cold-starting of CI engines
    - Better CI engine performance, namely less misfire/combustion instability, for light to medium load operation
  - Army request to add these two requirements, to Table A-1 for FT SPK, during last revision to MIL-DTL-83133F was dismissed, will try again for next revision
- **Different lubricity specification for DF-2 (HFRR) vs. JP-8**

BACK-UP SLIDES

What Are Biofuels?



Courtesy AFRL,
Dr. Tim Edwards

HRJ Properties Study

- **HRJ properties indistinguishable from F-T SPK**
  - Spec properties (density, freeze, flash, heat of combustion, etc.)
  - Contaminants (metals, oxygenates, etc)
  - Fit-for-purpose properties (lubricity, dielectric, cetane, etc.) (in progress)
  - Combustion operability and emissions (in progress)
  - Material compatibility (in progress)
  - Blend properties (in progress)
- **Issues (same as SPK!)**
  - Density of blend
  - Aromatic content of blend
  - GHG footprint/sustainability
  - Cost (feedstock for HRJ, plant cost for F-T)

Courtesy AFRL,
Dr. Tim Edwards