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PROJECT UPDATE: INCREASED FUEL AFFORDABILITY THROUGH DEPLOYABLE REFINING TECHNOLOGY

August 2016

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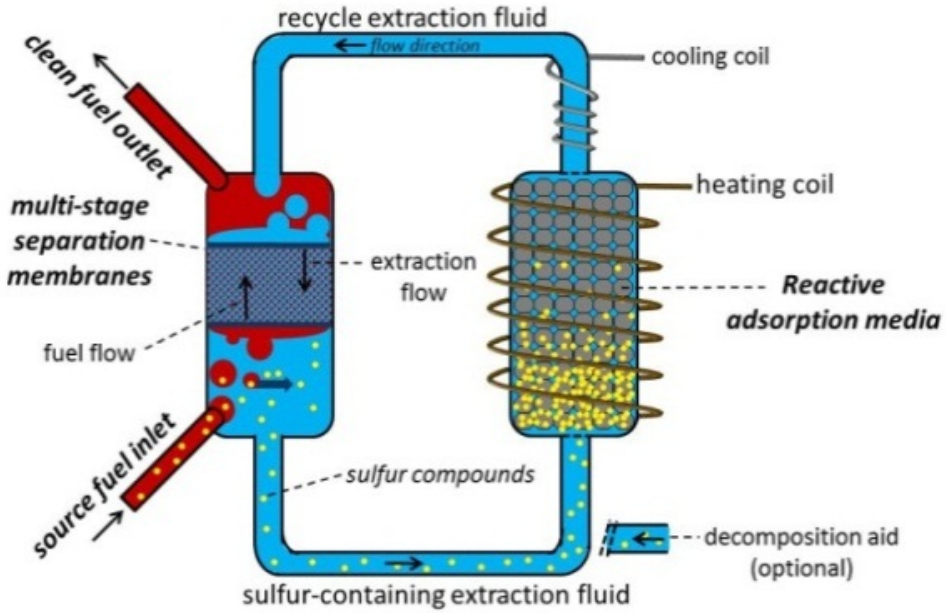
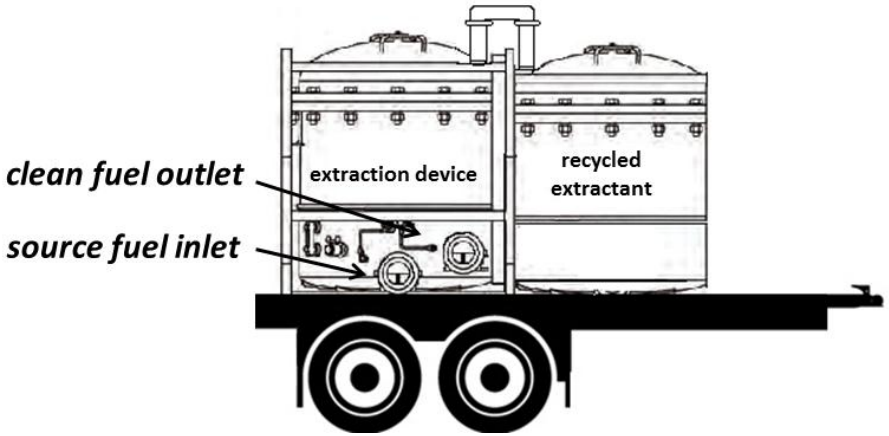
Overall Process Concept





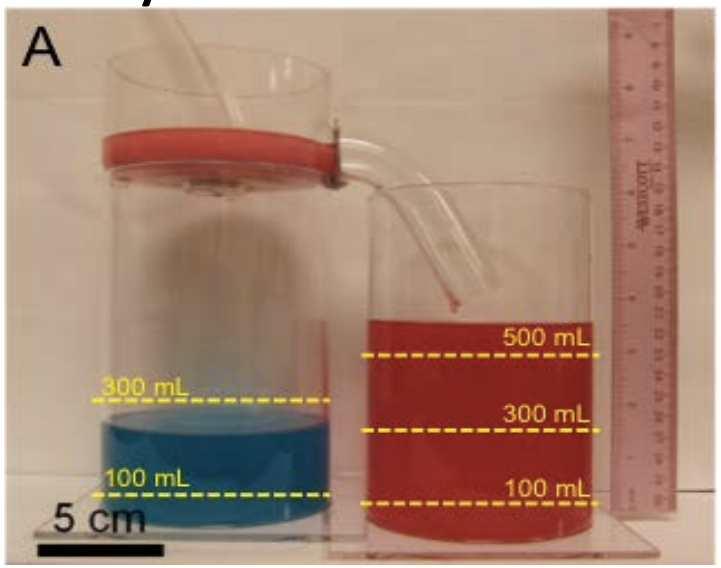
USAF Technology Basis

- **Combine two mutually exclusive adherent / repellent surfaces; coalescence of phases caused by droplet redirection rather than merging; small droplets take longer to merge but bounce readily**

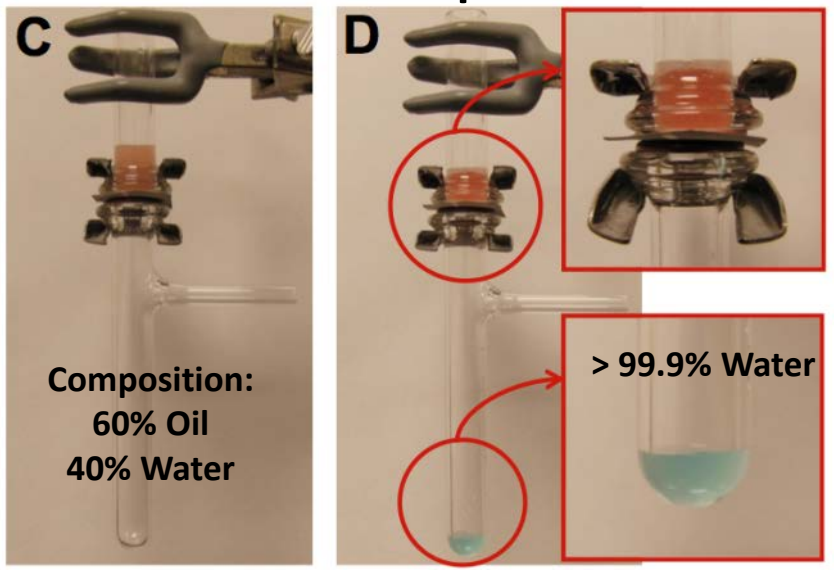
- **Result: a simple apparatus for the gravity driven, *continuous* separation of oil-water emulsions, proving that coalescence can be "short circuited"**

- **1 US patent, 1 application**

Gravity Driven - Continuous Flow

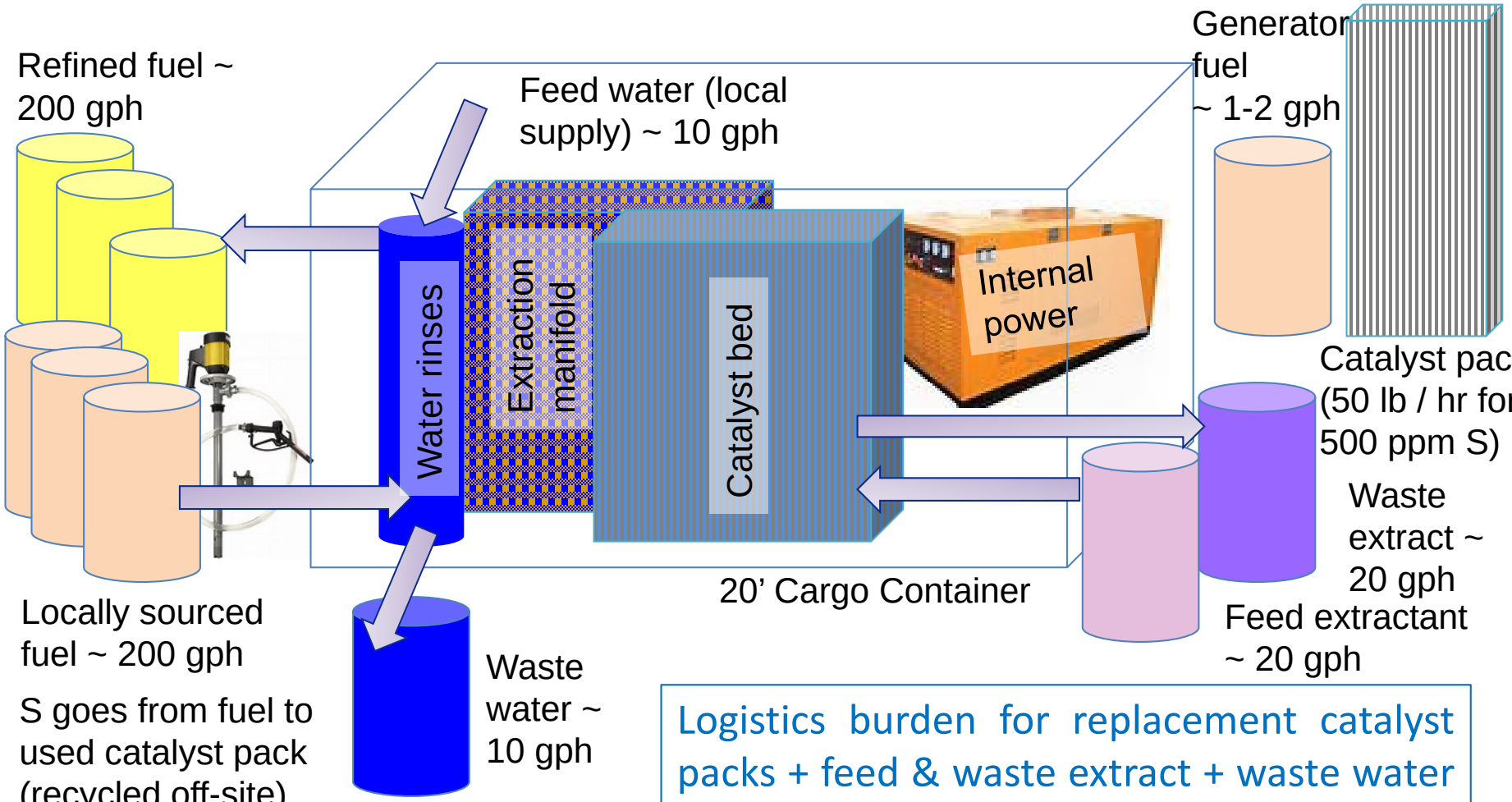


Emulsion Separation



In collaboration with Prof. Anish Tuteja at the University of Michigan.
Nature Communications, **2012**, *3*, Article number: 1025 DOI: doi:10.1038/ncomms2027

Refined Operating Concept



Extraction fluid = denatured (methanol or DB) ethanol / water 70 / 30 (vol)
Flow rates are prototype initial targets

Logistics burden for replacement catalyst packs + feed & waste extract + waste water + internal generator fuel << Logistics burden for shipping in clean fuel

Process Development Roadmap

50 gal / hr LLE, open loop

Units 1 and 2, complete, testing to complete in Sept 2016

"Unit 3"

200 gal / hr LLE, closed loop

Conceptual design complete, pilot components being fabricated, design will be completed as part of program by early 2017, construction decision pending

Bench reactive de-sulfurization

Complete, final tests underway

Scaled-up reactive de-sulfurization

In design phase, expected by Sep 2016

Year 1 Year 2 Year 3

Equipment Status

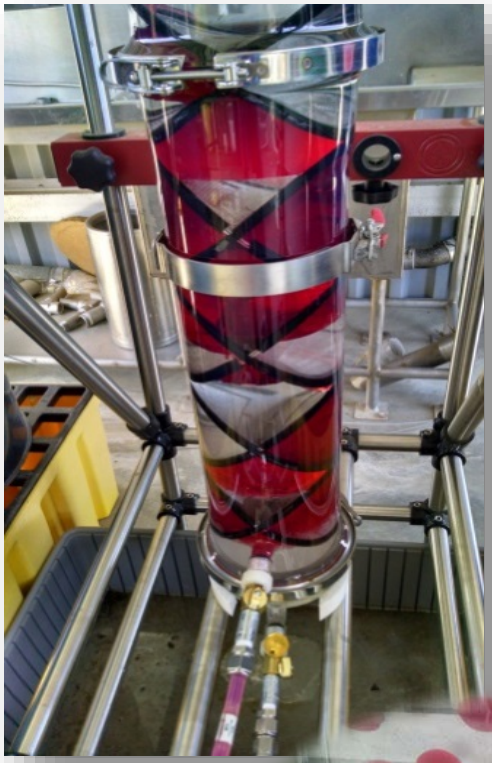
50 gal / hr LLE, open loop

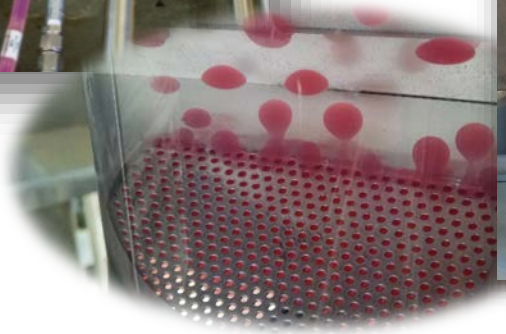
Unit 1: **Operational**
Location: EAFB Bldg 8498
Initial Operating Capability: 4 Feb 2016
Current status: Set-up for final experiments in progress, will become inactive after Sept 2016
Current Experiments: Validation of counter-flow stage height model

Unit 2: **Operational**
Location: WPAFB, AAFRF
Initial Operating Capability: 20 Jan 2016
Current status: Performing several test runs per month
Current experiments: Testing packed column configuration stage height model

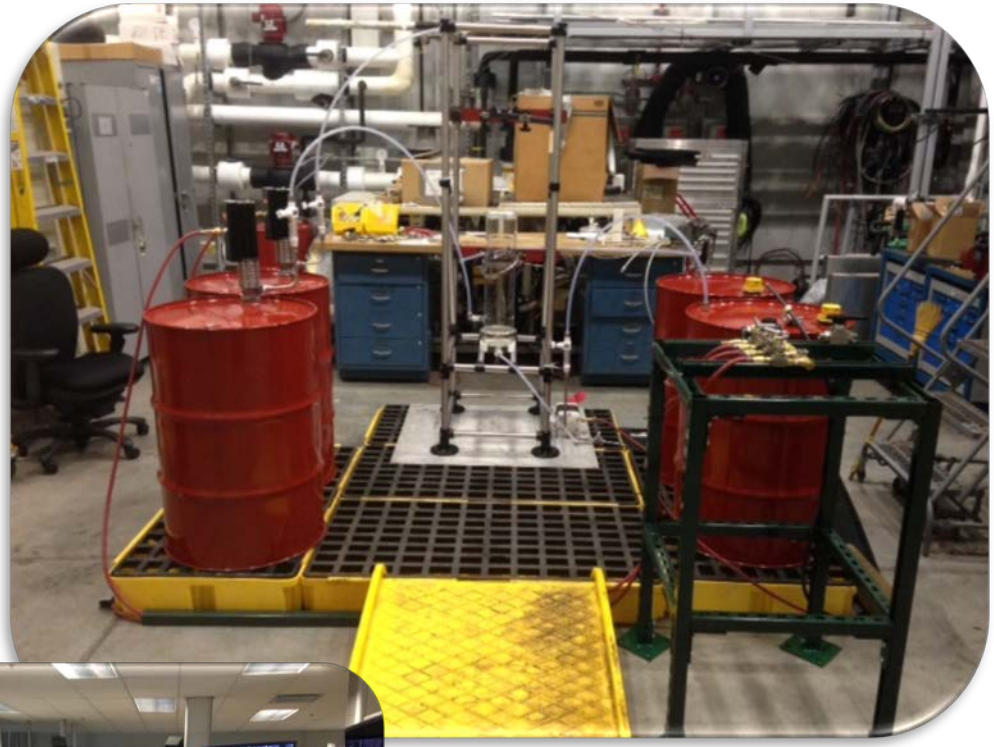
Unit 1 – Edwards AFB

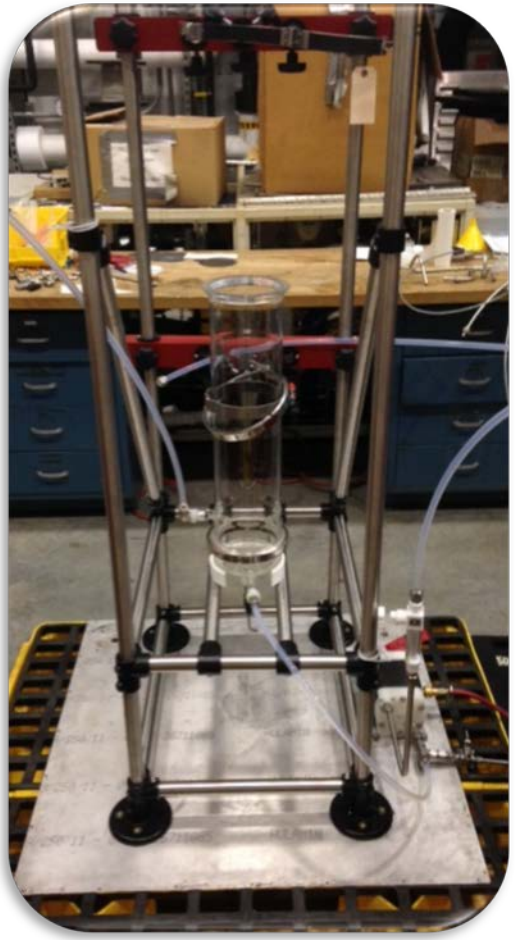
Unit construction completed: Oct 2015
Site prep for operations completed: Jan 2016
Operations commenced: 4 Feb 2016.

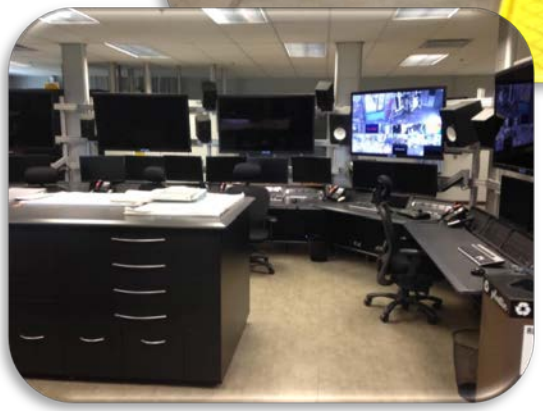




Unit 2 – WPAFB AAFRF

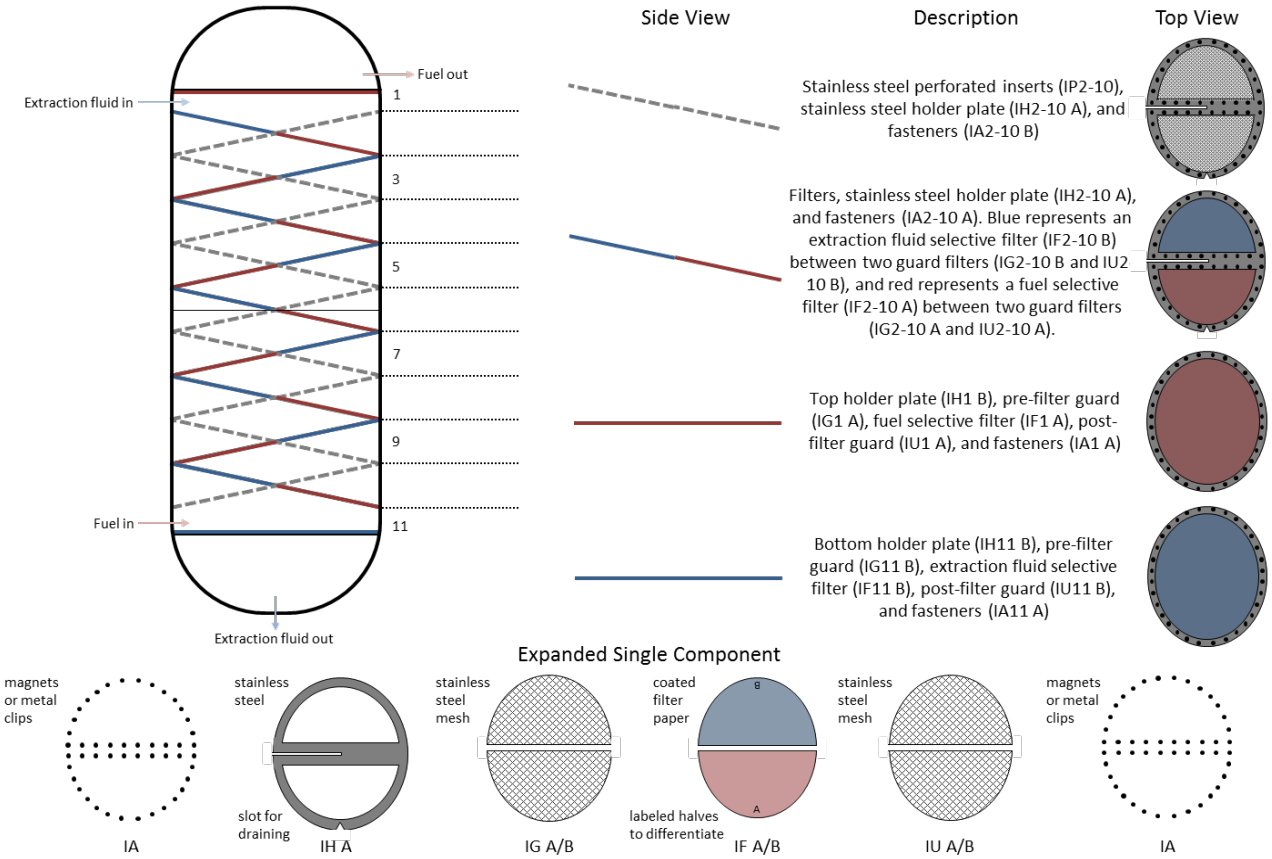






Completed Dec 2015; initial operation 20 Jan 2016; now performing baseline tests w/ jet fuel

Unit 1 & 2 Liquid/Liquid Extraction



Final experiments with Unit 1 will attempt to confirm that hydrostatic pressure needed for re-dispersion controls stage height; on-going experiments with Unit 2 will generate “equivalent stage” height data for packed column alternative.

Key Hypothesis 1:

Valid

Membranes allow successful operation under conditions that would normally cause flooding, *confirmed by experiment*

Key Hypothesis 2:

Limited validity

Stage height controlled by membrane geometry, *experiments show other factors can override*

Risks and Alternatives

University of Michigan is developing alternative high-performance extraction fluid in the event that the size of the extraction system needs to be reduced. Higher-performing fluids have been identified, but may impose unacceptable logistical or ESOH burdens.

University of Michigan is developing alternative mixing and dispersion techniques to allow for smaller stage heights (in the event the size of the extraction system needs to be reduced). Emulsification appears promising but may compromise final fuel quality.

Alternative catalysts with higher capacities, faster kinetics (particularly for certain sulfur-containing species) and potentially lower cost / easier preparation have been sought by the Naval Air Warfare Center, Weapons Division (in the event the size / refill frequency of the catalyst pack needs to be reduced). So far, no superior alternatives to the current catalyst have been identified. NAWCWD is investigating the potential for slightly elevated operating temperatures to improve catalyst performance. Discussion with USDA on alternative catalytic technology will be held in late August.

Near-Term Project Plans

Finish extraction experiments using Units 1 and 2 by September 2016. Data from these units will be used as part the analysis of alternatives during preliminary design of Unit 3.

Construct a pilot extraction section for Unit 3 (design nearly complete), fabrication to take 7-9 weeks in Sept / Oct 2016. The pilot section is 3 segments long, uses cross-flow extraction w/ membranes, and replicates a portion of the extraction manifold for Unit 3, which is expected to contain 50-150 segments.

Construct a pilot catalyst bed section for Unit 3 (design started in Aug 2016), expected 4 weeks for design + 4 weeks for building. The pilot section will use commercial catalyst and replicate a portion of the catalyst bed for Unit 3. Data from pilot sections will be used for detailed design of Unit 3, which will have 25-75 identical catalyst bed sections.

Design contract for Unit 3 to be developed in Fall 2016. RFI process on-going. Preliminary engineering study and detailed engineering design may be split into two separate activities.

Fuel Treatment Unit 3

Medium-Term Project Plans

Project will transition from AFLR/RQR lead to APTO lead in FY17.

Additional funding will likely be needed to construct Unit 3 (funding sources currently being sought). Construction is expected to take about 6 months and may be carried out by a commercial firm.

Once constructed, Unit 3 will be used to treat ~1000 gal of jet fuel to meet fit-for-purpose specifications for ultra-low sulfur diesel (< 15 ppm S). The treated fuel will be utilized in a ~40-hr engine test to verify operating performance characteristics.

Follow-on field demonstration opportunities may include treatment of overseas diesel fuel sources to meet fit-for-purpose specifications for ground equipment or treatment of locally available fuels for fuel cell feeds.

The fuel treatment technology IP is being licensed. Licensee will likely work with petroleum engineering firms for commercialization.