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A River of Energy Solutions

NAWCWD Alcohol-to-Jet Fuel Technology

A Linchpin Technology for a "Green" Jet and Diesel Fuel Solution

Naval Air Warfare Center Weapons Division RDAT&E Mission

NAWCWD Renewable Energy S&T Activities

Energy efficiency evaluations for Warfighter technologies

Hyacinth-Mediated Wastewater Purification

(e.g. heavy metals, sewage and industrial waste)

Biomass-to-Alcohol Conversion

(hemi-cellulose/cellulosic sugars from biomass to bio-n-butanol)

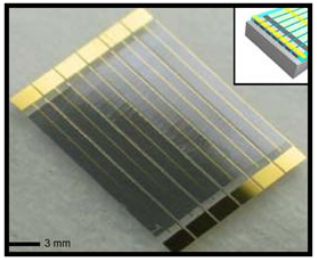
Synthesis of a Bio-based Fuel from Biobutanol

(Gas, diesel and jet fuel via Alcohol-to-Jet fuel technology)

Biomass-to-Energy Technology R&D Demonstration Center coupled to advanced Alcohol-to-Jet fuel technology

CO_2 capture and utilization R&D from Coso geothermal resource

Fuel cell and energy storage technology R&D



Advanced nanoscale solar photovoltaics, optics and semiconductor R&D

Remote operations energy production S&T

High density biofuels R&D for rockets/missiles and UAVs

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Energy and the Navy

Then and Now…

NAVY ENERGY

"Energy is a Force Multiplier and Strategic Resource"

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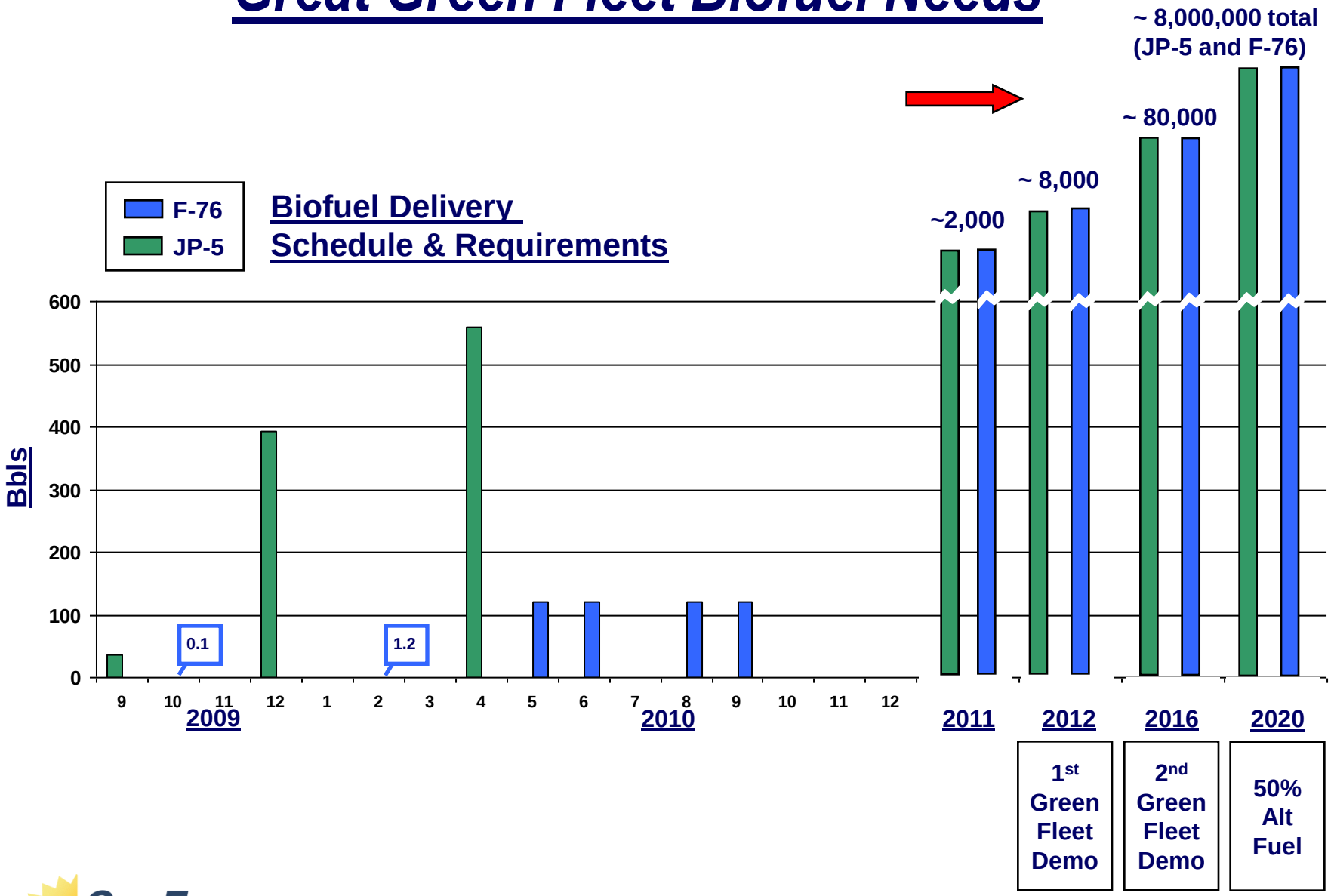
Why Alternative Fuels for the Navy?

- Energy and Economic Security
  - Joint Operating Environment 2010 report by the US military warning of supply shortages in the oil market of up to 10 million barrels/day by 2015 (linked to production capabilities)
  - For every $1 a barrel increase in oil, the Navy and Marine Corps pay more than $30 million
- Policy
  - ***"I'm directing the Navy and the Department of Energy and Agriculture to work with the private sector to create advanced biofuels that can power not just fighter jets, but also trucks and commercial airliners."***

    President Obama at Georgetown University, March 2011
- CNO Guidance:
  - Provide a Navy Energy Strategy that treats energy as a strategic resource
- Mission Requirements
  - Hawaii/Guam, Middle East and future forward operations (S. America, Africa, Asia?)
  - Fully-burdened cost of fuel ($ + lives)

Great Green Fleet Biofuel Needs



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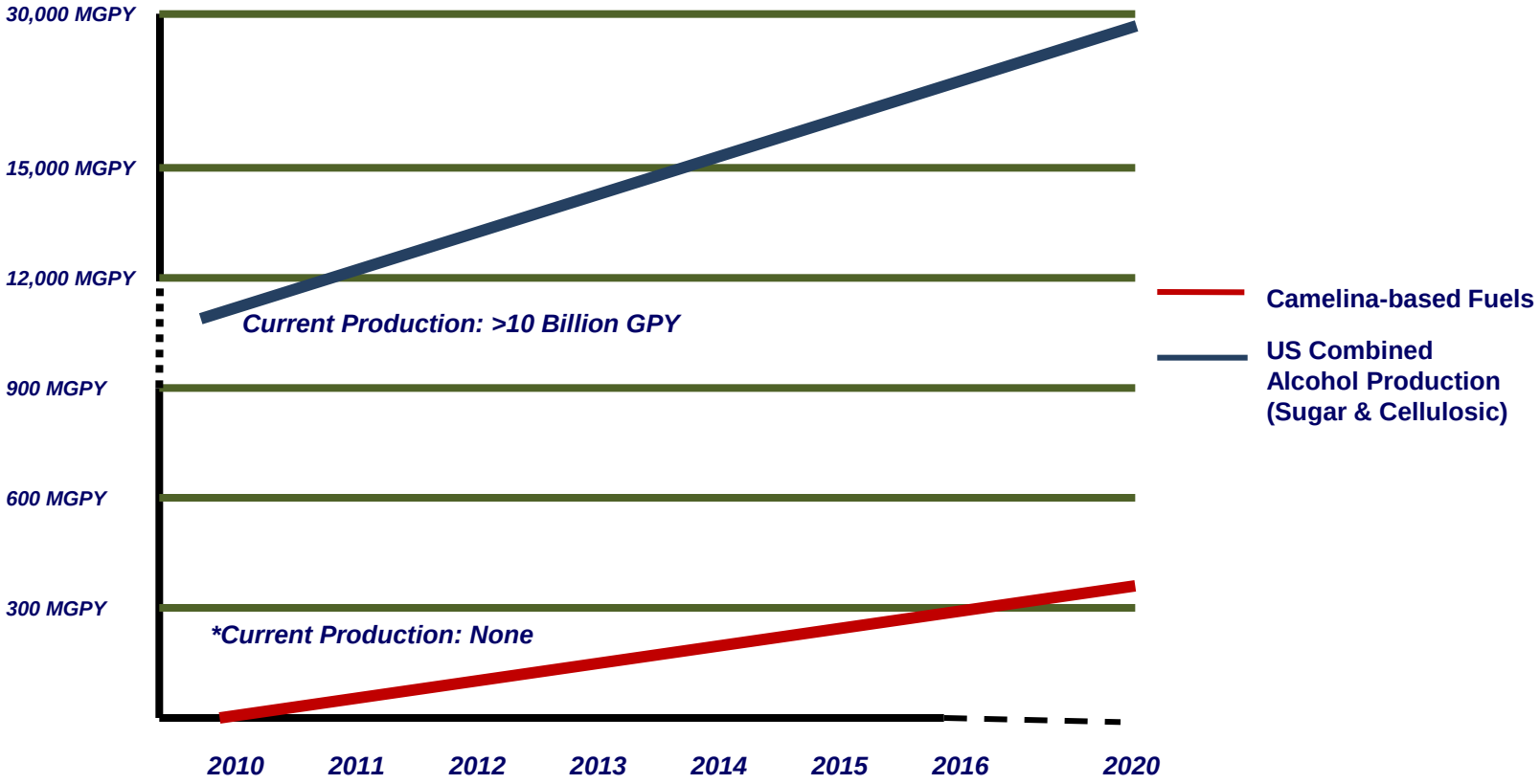
Current and Projected Biofuel Production Capabilities: Alcohols (Ethanol) vs. Triglycerides (HEFA)



***Plant and algae HEFA-based jet fuel production will require large capital influx by industry and public to build production capabilities**

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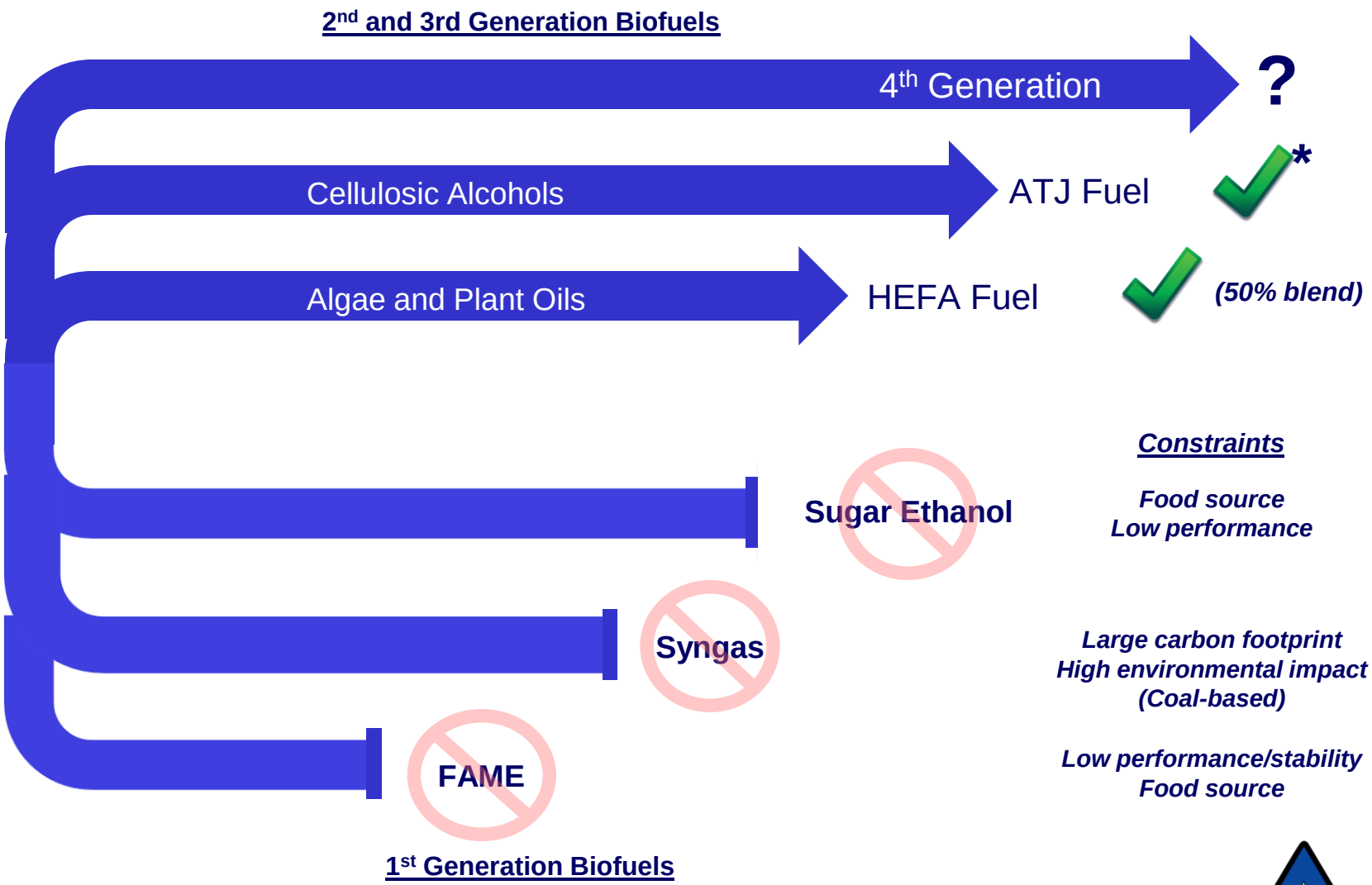
What Factors Lead to a Successful Military Biofuel?

Key Considerations

- Commercial viability
- Market acceptance
- Political support
- Infrastructure compatibility
- Feedstock sustainability
- Price parity
- Carbon footprint
- Fit-for-Purpose/Performance
- Capital expenditures
- Technical merit
- ? ? ? ? ? ? ? ? ?

Approaches to Meet Navy Fuel Requirements



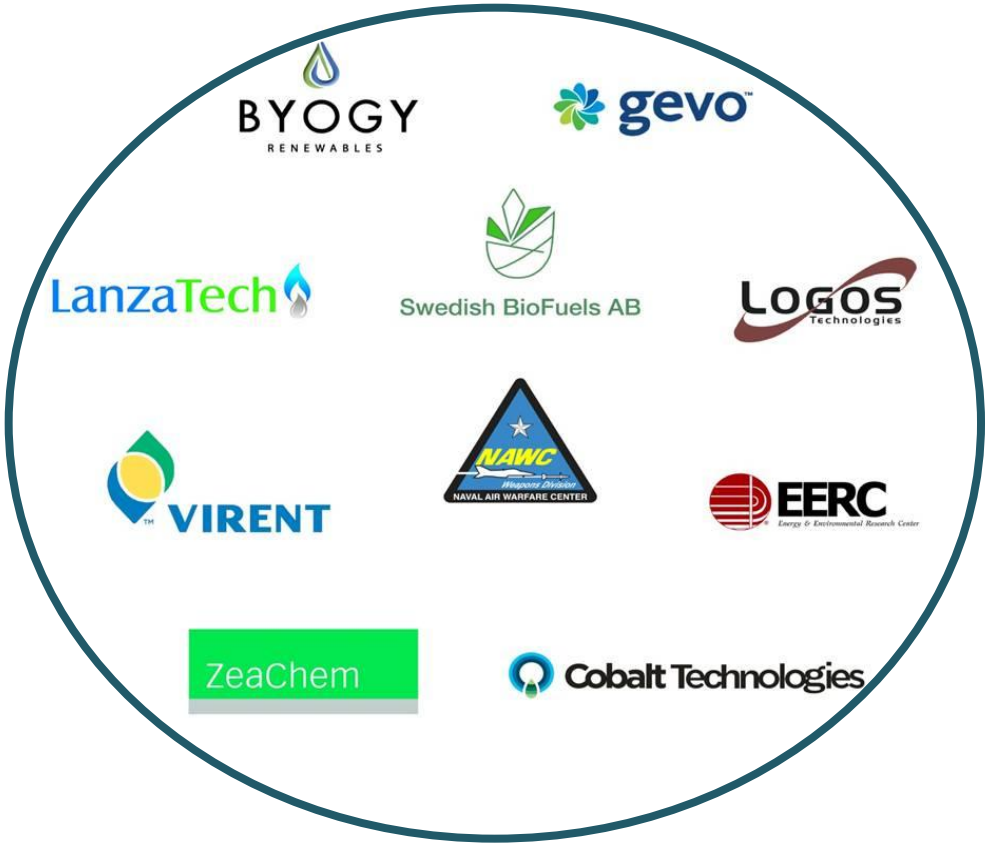
* *As part of the ASTM D7566 ATJ appendix for jet fuel and undergoing testing/certification by the Navy and Air Force*

Genesis of Alcohol Fuel Technologies

- Why use biomass-derived alcohols as a potential fuel source?
  - Sugar/starches, hemicellulosic and cellulosic feedstocks most abundant, renewable resource on planet
    - Sugar/starch sources used mainly as food crops
    - >40 million tons/year of combined waste biomass generated by U.S.
  - Fermentation chemistries well understood and part of the natural carbon lifecycle
    - New technologies will increase ability to derive high-energy fuels from waste hemi-/cellulosic biomass feedstocks
      - Quicker, cheaper, more efficient/effective biomass sugar extraction technologies
      - Quicker, cheaper, more efficient/effective sugar-to-alcohol conversion technologies
        - » Current at 80% of theoretical yields

The Alcohol-to-Jet Fuel ASTM Task Force

"Our objective is to accelerate the adoption of bio-fuels and blended logistic fuels . . . To achieve these goals, we have invested in research about engine performance, materials compatibility, fuel stability, and bio-fuels and renewable energy." *RADM Carr, Chief of Naval Research, March 1, 2011*



"Because while the military can lead, it's going to have to be industry that expands the market," *SECNAV Mabus; June 8, 2011*

"I'm directing the Navy and the Department of Energy and Agriculture to work with the private sector to create advanced biofuels that can power not just fighter jets, but also trucks and commercial airliners." *President Obama March 2011*

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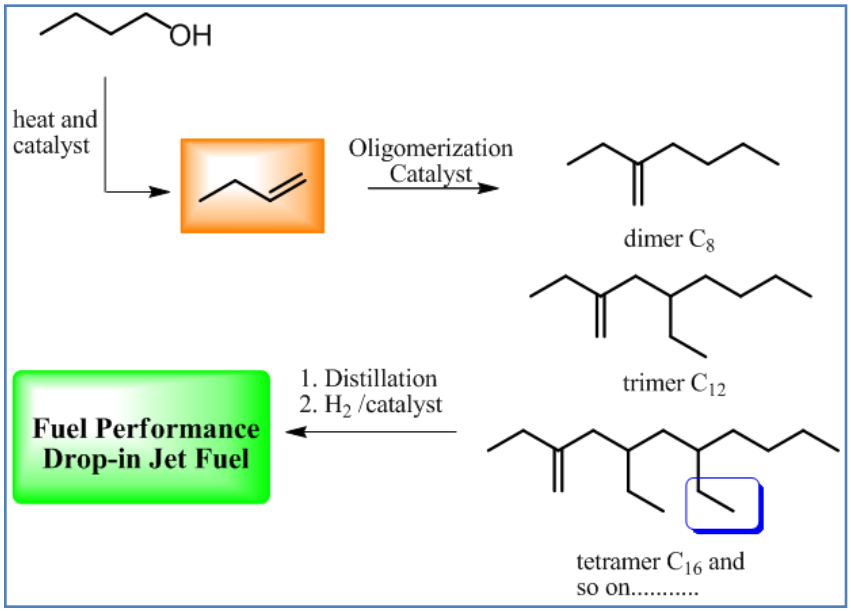
NAWCWD's Alcohol to Jet Fuel Technology



n-butanol derived fuel products have diesel, marine and jet fuel properties

Bio-lubricants are also produced from conversion process

Jet Fuel Process Commercial Integration

2012-2014

n-Butanol to Jet Fuel Process Demo Plant

2012

Discovery, Patenting, and Publishing of ATJ Technology

2007-2011

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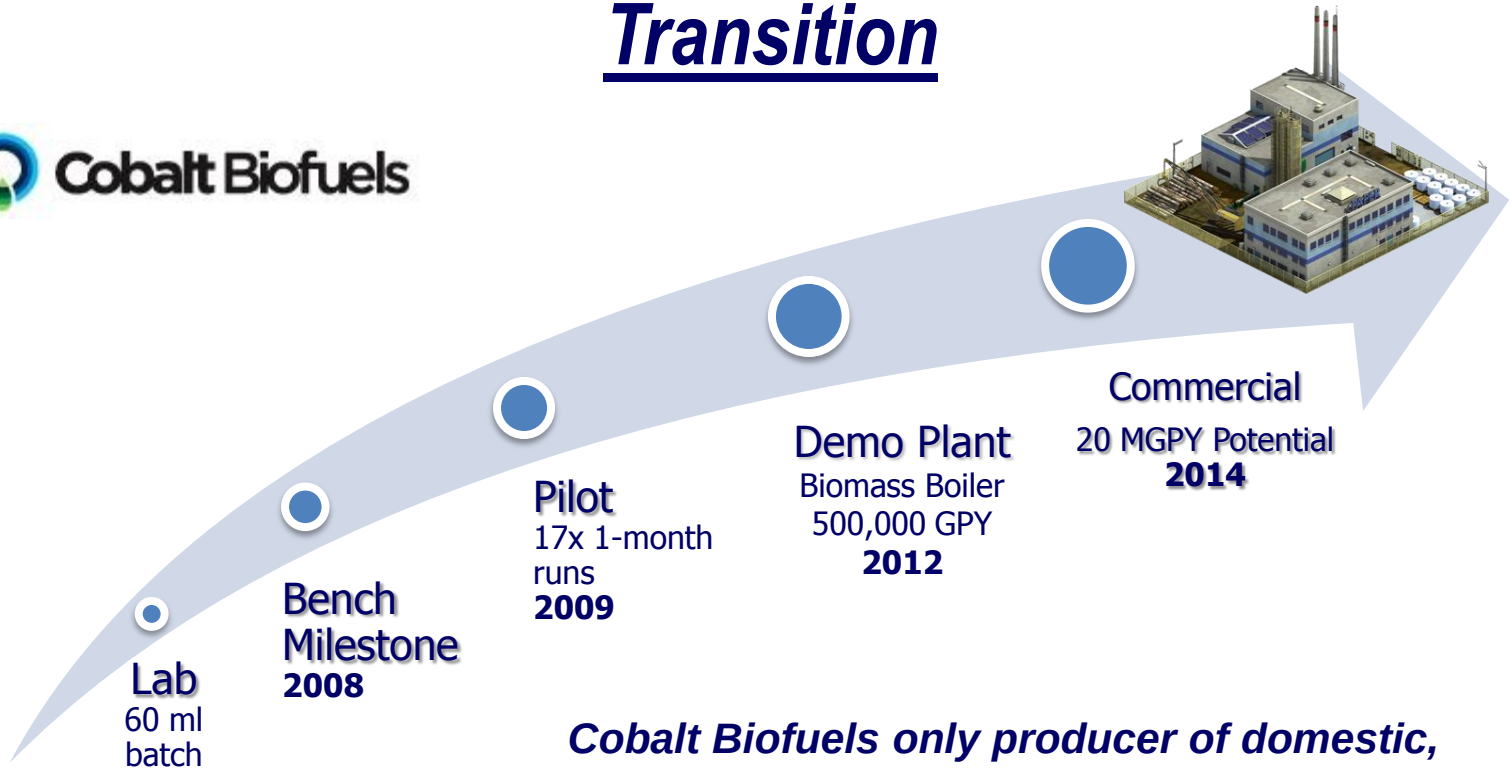
**NAWCWD Discovery Team:*
Michael Wright, Benjamin Harvey, & Roxanne Quintana

Industrial Partnerships to Accelerate Technology Transition

Cobalt Biofuels



Cobalt Biofuels only producer of domestic, non-fossil, renewable (cellulosic) n-butanol

Demo Plant located in Alpena Michigan utilizing waste biomass from paper mills

Commercial plant will look at dedicated bioenergy feedstocks

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Integration of Commercial and DoD Timelines

Cobalt Biofuels

Lab
60 ml batch

Bench Milestone
2008

Pilot
17x 1-month runs
2009

Demo Plant
Biomass Boiler
500,000 GPY
2012

Commercial
20 MGPY Potential
2014

Discovery, Patenting, and Publishing of ATJ Technology
2007-2011

n-Butanol to Jet Fuel Process Demo Plant
2012

Jet Fuel Process Commercial Integration
2012-2014

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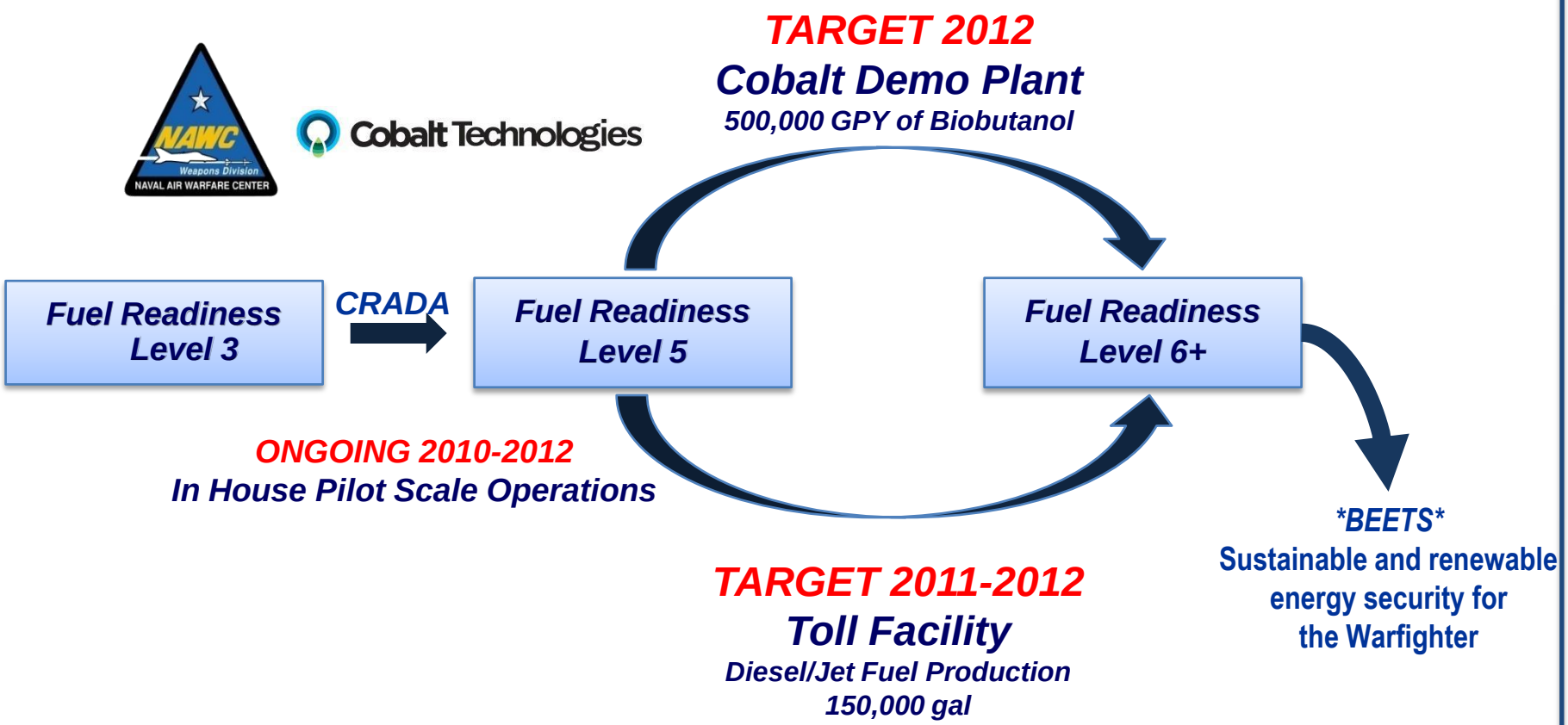
Accelerated Fuel Technology Development



Fuel Readiness Level (FRL)

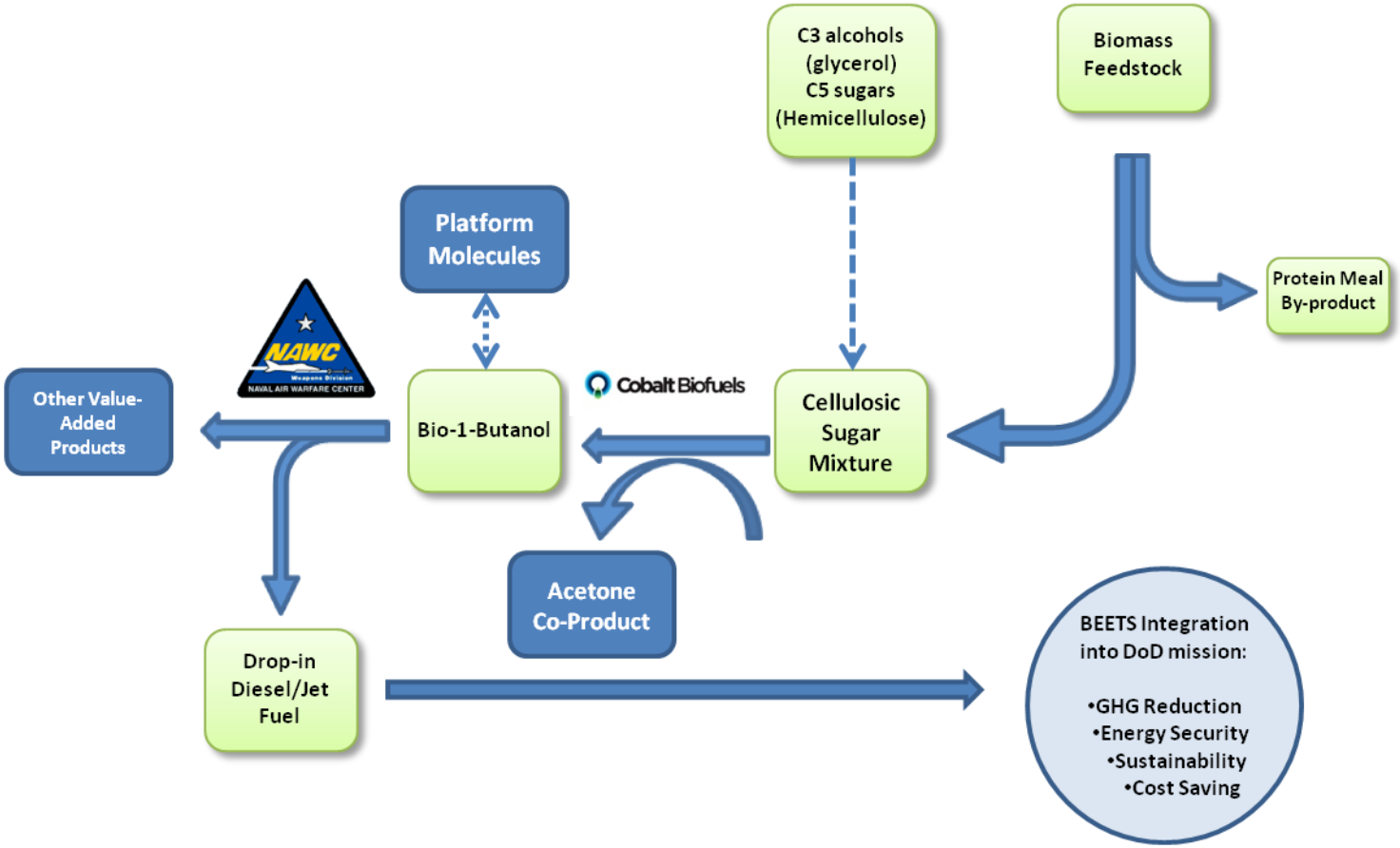
FRL3: Proof of Concept; Lab scale fuel sample

FRL5: Process Validation; Scaling from lab to pilot plant

FRL6: Full-Scale Technical Evaluation; Fitness, fuel properties, rig and engine testing

Biomass-to-Energy Enterprise Technology Suite *BEETS*

Integrated Technology Process Diagram



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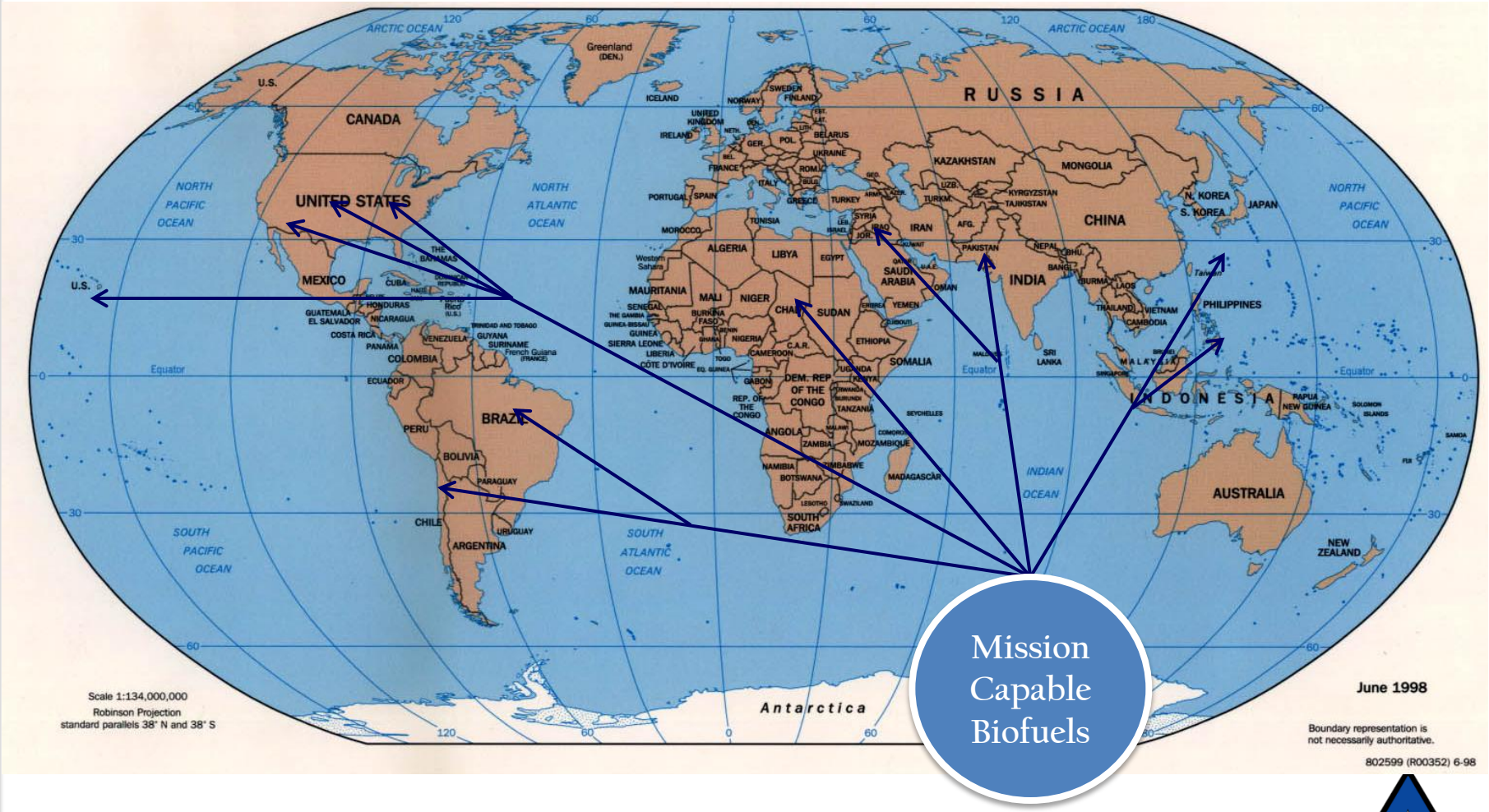
A Global Technology for the Warfighter



Mission Capable Biofuels

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Summary

- NAWCWD's alcohol-to-jet fuel technology is one of several biofuel technologies in support of the Navy's renewable fuel goals
  - The ATJ fuels have the production capabilities of the billion gallons/year based the on the current alcohol infrastructure
  - The diversity of biomass feedstocks and methods for making alcohols will ensure competitive and sustainable biofuel pricing and stability
- The collaboration of Navy research with industry will accelerate transition of biofuels to the warfighter
- The Navy mission is diverse in terms of energy requirements—as resources become more scarce, flexibility and versatility will be key

Acknowledgements

- This presentation and work is supported by the leadership and scientists of the Naval Air Warfare Center Weapons Division
- Thanks and appreciation to the Office of the Deputy Assistant Secretary of the Navy (Energy), PACOM and GovEnergy

100% "Bio-Fueled" Platform PACOM-Style

Thank you!

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