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Evaluating Sustainable Aviation Fuels: A Decision Support Dashboard for Comparing Ammonia and Fischer-Tropsch Fuel Blends to JP-8

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Abstract: The U.S. Air Force's (USAF) future aviation capabilities depend on innovative and sustainable fuel solutions that can enhance performance while addressing environmental, economic, and supply chain challenges associated with procuring, producing, and delivering JP-8, the primary jet fuel for the USAF. Utilizing a Decision Support Dashboard, the research develops a forward-compatible model capable of quantifying advantages and drawbacks of any alternative fuels. The research involved developing a dynamic decision support tool that specifically assesses the value of Trident Fuels for military operations, considering factors such as cost reduction, mission flexibility, and emissions. By identifying optimal fuel blends of Ammonia and Fischer-Tropsch, this model projects savings of $1.4 to $2.4 billion USD from the current $10.3 billion USD USAF fuel budget, and a 99% decrease in net carbon dioxide (CO_2), raw aromatics, and raw sulfur emissions.

Keywords: Sustainable Aviation Fuels, Trident Fuels, Decision Support Dashboard (DSD), Military Aviation, Cost Reduction, Excel-based Decision Support Tool.

1. Introduction

The future of military aviation hinges on the ability to harness innovative and sustainable fuel solutions that not only enhance performance but also mitigate the environmental, economic, and supply challenges posed by traditional jet fuels. This research aims to address the high cost and unsustainable practices associated with the procurement and production of JP-8. Trident Fuels is tackling that problem by proposing fuel blends of Ammonia and Fischer-Tropsch (FT). A decision support dashboard was developed used to quantify the value Trident Fuels has for US military operations at home and deployed. This allows leaders to change mission specifications to fit their needs and see how Trident Fuel's value is not limited to its environmental benefits. This tool is based in Microsoft Excel. The user-friendly design of the tool in Excel makes it easy for all users to make more informed decisions. Furthermore, the ubiquitous use of Microsoft Excel on government systems allows this tool to run on any computer.

1.1 Problem Statement

The United States Air Force faces several risks with current military aviation fuels including supply insecurities, environmental impacts, and health concerns. Analyzing these challenges of JP-8, which include high cost and unsustainable practices, is key for decision makers. Currently, there is no comprehensive tool for quantifying and comparing fuel options that keep cost reduction, mission sets, and sustainability in consideration.

1.2 Related Work

Currently, Fisher-Tropsch (FT) and ammonia are not widely used in the transportation or military industries. However, large amounts of research are being conducted in this space. As the world gains a better understanding of the adverse environmental impacts of burning fossil fuels, the technology industry will innovate and advance to support the engineering needed to make such alternative fuels feasible. FT is a process that takes carbon monoxide (CO) and hydrogen and converts them into hydrocarbons which are burned as fuel. While production is more expensive than traditional fuels, it is much more environmentally friendly; FT fuels produce considerably less polynuclear aromatic hydrocarbons (PNAs), no sulfur oxides (SOx), and no nitrogen oxides (NO_x) when manufactured from green hydrogen from water feedstock. Ammonia is also under review as an alternative fuel to fossil fuels as a clean and accessible energy source. The energy density of ammonia is comparable to gasoline and is compatible with existing infrastructure, thus changes to engines that need to be made to accommodate ammonia will be minimal.

Carter (2012) provided a comprehensible evaluation of alternative jet fuel technologies, with a specific focus on military aircraft emissions. Military planes emit lower levels of NO_x but higher levels of CO and unburned hydrocarbons. Unconventional fossil feedstocks such as Gas-to-Liquid and Coal-to-Liquid processes, while boasting impressive production capabilities, have similar environmental impacts to conventional fuels. FT facilities pose the familiar challenge of cost, further highlighting the military's main challenge in its endeavor to transition to alternative jet fuels: balancing energy yield, environmental impact, and cost to realize its objectives.

Muzzle et al. (2006) conducted research with various FT blends in military equipment and found them to be compliant with JP-8 guidelines. The methodology used to evaluate FT is valuable, as it provides objective criteria that are used to evaluate a fuel's efficacy. While useful for Contiguous United States (CONUS) operations, the paper lacks information on Outside the Contiguous United States (OCONUS) FT applications which the team intends to expand on.

Hileman and Stratton's (2014) analysis explores the relevant factors that should be considered when analyzing the true overall value of using non-JP-8 fuel. They identify six criteria. First, is the economic cost of production, which includes the cost of changing infrastructure. Second, technical feasibility with current aircraft. Third, global climate change impacts. Fourth, air quality impact. Fifth, resource impact such as land and water needed to produce non-renewable fuels. Sixth, technological readiness.

Erdemir and Dincer (2020) propose ammonia as an alternative fuel with benefits including carbon-free emissions, economic feasibility, and low specific energy cost. Challenges include high ignition temperature and NO_x emissions. These challenges associated with ammonia can be entirely mitigated by combining ammonia with traditional fuels and using chemical catalysts.

1.3 Organization

For the remainder of this paper, Section 2 describes the methodology and data, Section 3 describes modeling and analysis, and Section 4 is the conclusion. All abbreviations and definitions of terminology used can be found after Section 5, references.

2. Methodology and Data

2.1 Data

Spark Industries Trident Energy and the Defense Logistics Agency (DLA) Energy provided data that was used in this research project. The Spark Industries data includes specific A-10C range data using Trident Energy synthetic fuels shown in Table 1, a breakdown of the ammonia production system and cost of infrastructure to create ammonia fuel, and a fuel-cost model of price breakdowns for JP-8, FT, and ammonia fuels shown in Table 2. The data provided is solely for the A-10C, and extending this method to other aircraft will require the corresponding data. Research is currently being conducted with Trident Energy's fuel blend with changes to engine infrastructure and it is possible to see almost 800% increases in combat range for the F-15E. Those numbers were not included, as we did not have that information while creating the model.

Table 1: A-10 Flying Range Data Based on Fuel Mixture

Range Data Table A10-C					
Component 1	Component 2 (FT	Trident Standard Range	Trident Max Range	JP8 Standard Range	JP8 Max Range
100	0	531	794	800	1196.262
99	1	532	795	800	1196.262
98	2	537	802	800	1196.262
97	3	539	806	800	1196.262
96	4	542	811	800	1196.262
95	5	545	815	800	1196.262

Table 2: Trident Energy Synthetic Fuel Cost Breakdown for Specific Blend

Trident X- Fuels	production cost$/ton	$/lb	$/gal	$/barrel
Ammonia Component	$ 391.13	$ 0.20	$ 1.27	$ 53.14
FT Component			$ 8.01	$ 336.42
99/1 Trident Fuel			$ 1.33	$ 55.98
90/10 Trident Fuel			$ 1.94	$ 81.47
80/20 Trident Fuel			$ 2.61	$ 109.80
50/50 Trident Fuel			$ 4.64	$ 194.78
30/70 Trident Fuel			$ 5.99	$ 251.44
10/90 Trident Fuel			$ 7.34	$ 308.09

The DLA Energy FY 2022 Fact Book provided data for the transportation costs to get JP-8 fuel to military bases, both CONUS and OCONUS. This information paired with DLA Energy's Memorandum of FY 2023 Standard Fuel Price was used to get a true cost per gallon of JP-8. Data on the composition of fuels and their emissions was found in an article written by Edwin Corporan. These numbers were used to calculate total emissions for a given mission and blend of fuel.

Lastly, Trident Energy provided data on numbers for energy input for hydrocarbon synthesis, which is 57.175 kilowatt hours/kilograms of hydrogen. This number was used to find the energy input to create the proposed fuel.

2.2 Methodology

A Decision Support Dashboard (DSD) is used as the methodology to analyze Trident Fuel (TF) and JP-8 side-by-side. DSDs amalgamate data and knowledge from different sources to provide users with valuable information more easily analyzed through a user-friendly interface. The objective of the DSD is to provide the user with the optimal TF blend and fuel benchmarks given their mission requirements, allowing for easy comparison between the desired fuels. This will allow users to make more informed decisions concerning their specific mission.

The DSD takes simple inputs from a user, the decision maker, to compare TF under different scenarios and requirements (shown in upper left section of Figure 1, Questions 1-6). It then displays the optimal fuel blend, determined by desired miles flown per sortie, compared to traditional JP-8 in two metrics: cost and emissions. Cost and emissions values for TF fuels and JP-8 are calculated in the background of the tool and are based on data shown in Section 2.1.

A display of the decision tool is shown in Figure 1. First, the tool allows users to input their mission requirements: number of sorties flown per week and desired number of miles flown per sortie. The DSD will then take these mission requirements and output the Trident Energy recommended blend with the maximum amount of Ammonia. The results section of Figure 1 displays the recommended blend needed to meet mission requirements, the gallons to be produced daily, and the number of TF production systems required. The number of gallons of fuel produced and production systems required go directly into calculating the fixed and variable costs of the proposed alternative fuel. It will also compare the results for cost and emissions between the two fuels.

The tool also uses visuals to highlight the potential benefits and drawbacks of both fuel types, shown through the graphs in Figure 1. For example, the current inputs find that there is a significant cost difference between the fuels for a range of 533 miles. The graphs also highlight the value of FT and ammonia to reduce harmful emissions.

The tool also provides objective metrics by highlighting the benefits and drawbacks of Trident Fuel in comparison to JP-8 currently in use. The output shows the difference in the listed performance metrics between Trident Fuel and JP-8, given the user's priorities and mission sets. By juxtaposing the statistics for each fuel, the dashboard easily shows a decision-maker the trade-offs for using each fuel.

3. Modeling and Analysis

3.1 Modeling

The two primary focuses of the DSD are to properly combine large amounts of data from the pool of sources needed to compare Trident Fuels against JP-8 and create a functional user interface that more easily allows a decision-maker to visually and empirically see the benefits and drawbacks of each type of fuel.

To properly combine the data, numerous equations in the tool calculate outputs and graph values. These calculations put all data into standardized units, determine the number of gallons per sortie based on user input, calculate additional costs per gallon of JP-8 based on transportation, store the data for the number of gallons of TF fuel that can be produced per production unit, compute the FT standard system suggested funding profile, and yield the emissions outputs based on different TF fuel blends.

The calculations rely heavily on the application of aeronautical principles to calculate TF burn performance. An example is one pound of JP-8 containing a higher energy density than one pound of TF. This difference will lead to different aircraft weights that directly affect the platform’s coefficient of lift and drag profile. These values are necessary to determine the range and the expected performance of the A10-C under TF fuels.

Figure 1: Decision Support Dashboard User Interface

3.2 Analysis

When finding the optimal blend with its associated cost and emissions, assumptions needed to be made based on the lack of certain information. The first assumption, which is associated with cost, is that Air Force bases are purchasing and installing TF production systems. That associated cost for buying each system then goes into the cost calculation. An alternative could have been that the bases lease or rent the systems, however, as these systems are novel, concrete data is not yet available for leasing options. A second assumption also associated with cost is the price of hiring TF operators is negligible. With training on Trident's fuel production systems, current fuel chemists and maintainers will shift their primary focus to operating and maintaining TF systems rather than JP-8 systems and production. This also reduces costs significantly as every Air Force member makes a set salary, based on their rank, therefore reducing the number of non-DOD members who make varying, potentially larger salaries, required in this process. A third assumption, affecting the range of the aircraft, is that the A-10C is only using its internal fuel tanks. The plane can utilize three external fuel tanks allowing it to hold more fuel for longer flights. Without utilizing these tanks, the range is lower for both TF and JP-8 than its maximum capability. Lastly, data about the composition and emissions of TF is assumed to be the same as fuels with the same chemical formula. The fuel is currently undergoing testing, so specific emissions numbers are unavailable.

After accounting for these assumptions, following observations were made: Because Trident Energy has a varying price range while JP-8 is constant, when CONUS, sorties with a range of 645 miles would result in the Trident blend being cheaper, based on price per gallon, than JP-8. When OCONUS, Trident is cheaper, based on price per gallon, at 654 miles or less. While FT contributes to more range, it is more expensive to produce than JP-8. This means that Trident will become more expensive than JP-8 at higher ranges. Another observation was that no matter the blend, Trident always has fewer emissions. At its highest emission blend, it still has significantly lower emissions than JP-8, and as more ammonia is incorporated in the blend, it continues to reduce emissions significantly, as ammonia, with chemical catalysts, burns clean. This is just one of the contributing factors towards the benefits the Trident blend has over JP-8.

3.3 Future Actions and Discussion

This DSD is flexible and can incorporate additional data and metrics as they become available. This model can be used to compare any fuels side-by-side based on three of the primary metrics of value to the Air Force: meeting mission requirements, cost, and environmental impact. With the current fuel market looking into many viable alternative energies, tools are needed that can clearly show comparisons between different fuel sources. The DSD's format, including its background calculations, accomplishes this quickly. For future comparisons, if a user inputs the relevant data into the background data sections, the tool can complete the necessary calculations for interface output.

Despite the functionality of the DSD, there are still many qualitative metrics that it cannot consider. The first is the resiliency of the fuel. Trident Energy Fuels specifically are extremely resilient as an on-demand and on-site fuel option. Under a military context, this means the price will not fluctuate as unpredictably as other fuels during conflict. For example, when the conflict in Ukraine began in 2022, the price of oil jumped 70% (Zhang, 2024). When producing fuels on-site, these prices will fluctuate much less, providing a huge advantage for military forces.

A second qualitative metric is the role Trident Fuel production systems can play in the US Air Force's current strategy of Agile Combat Employment. TF systems can provide fuel in austere locations for small bases. This would imply that the Air Force could establish an Air Base in any location large enough to prepare a runway and move assets accordingly without the need for a fuel supply line. With this, aircraft are easily able to move from base to base, making it much harder for opposing forces to target and eliminate them. This portion of the analysis is worthy of consideration in future research. The benefit a mobile fuel generation system would provide the military is intangible.

For future actions, the current tool can only be applied to the A10-C platform but can easily be applied to any aircraft given flight data. For example, if provided the aerodynamic profile of an F-15, the values to generate sortie range for the aircraft using Trident Fuel would be automatically calculated due to the preexisting framework of the tool.

4. Conclusions and Recommendations

Our research has demonstrated the potential of Trident Fuels as a viable alternative to traditional jet fuel, JP-8, for the USAF. Our DSD allows decision makers a user-friendly interface to easily compare alternative jet fuels using metrics that matter to them: meeting mission requirements, cost, and environmental impact. It also provides a discussion and alternative options section to add qualitative context to further inform the user's fuel decision.

Due to the cost savings of switching to Trident Energy Systems of $1.4 to $2.4 billion USD from the current USAF fuel budget, along with a substantial 99% decrease in net C02, raw aromatics, and raw sulfur emissions, serious consideration of Trident Energy Systems by the USAF is recommended. With continued investment in research and development to refine TF production processes and reduce costs, collaboration with industry partners to accelerate testing and certification of TF blends for use across various aircraft platforms, and integration of TF production systems into USAF infrastructure to enhance operational resilience and flexibility (aligning with the principles of Agile Combat Employment), both the quantitative and qualitative benefits of alternative fuels can be harnessed as the next greatest innovation to the USAF.

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Abbreviations:
CO: Carbon Monoxide
CO2: Carbon Dioxide
CONUS: Contiguous United States
CTL: Coal-to-Liquid
DSD: Decision Support Dashboard
FT: Fischer-Tropsch
GHG: Greenhouse Gas
GTL: Gas-to-Liquid
JP-8: Jet Propellent 8
NOx: Nitrogen Oxides
OCONUS: Outside the Contiguous United States
PNA: Polynuclear Aromatic Hydrocarbons
SOx: Sulfur Oxides
TF: Trident Fuels
UHC: Unburned Hydrocarbons