ILF

A Study of the Implications of Liquid Fuel (ILF) for Rotary Aircraft in Future Warfare

OR 680 / SYST 798 Project Proposal

Sponsored by:

Sikorsky
A United Technologies Company

ILF Team:

Hong Tran (SE)
Jessica Kaizar (OR)
Tariq Islam (SE)

George Mason University

TABLE OF CONTENTS

1 PROBLEM DESCRIPTION

1.1 Background

The industrial world, as it stands today, is dependent upon liquid fuel. From civilian vehicles to aircraft, from rocket propulsion systems to military vehicles, all forms of transportation are supported by liquid fuel. As such, fuel efficiency has become a hallmark in engineering and production of all different types and forms of vehicles that use fuel today.

The most notable reason for the new focus on fuel efficient vehicles and engines is due to the fact that the price of fuel has begun to rise. Consumers are now taking the fuel effectiveness of their vehicles into far more consideration now than ever before. Fuel, as a commodity, is now being seen within a more critical scope in terms of usage and availability. Just as everyday consumers are giving focus to fuel efficiency in their vehicles, so is the United States military.

Today, the US military (DoD) consumes more oil and petroleum than the 300 million consumers that reside within the US. The US military is actually the largest consumer of liquid fuels in the world, with fuel use in 2004 being the equivalent consumption level of the entire country of Greece. Within the construct of Operation Iraqi Freedom (OIF) and in the years pursuant, as of 2005, the US military was consuming 1.7 million gallons of fuel *per day*, which averages to about 9 gallons of fuel per deployed soldier. These metrics are in stark contrast to past wars, where by comparison, three weeks of fuel usage in the recent Iraq War equates to the total fuel usage of *all* Allied forces in World War 1. [1]

The US military must seek out more fuel efficient / alternate energy-based vehicles for its operations and update its tactics in future war campaigns, or risk substantial increases in cost to the American people. One such vehicle that the US military, and therefore their vendors, must consider are those with rotary engines and helicopters. Helicopters, from an engineering perspective, are the least fuel efficient vehicles in use today in the campaign scenario. However the advantage provided by rotary aircraft make them an essential part of military operations.

1.2 Problem Statement

The need of the US military and the DoD to have helicopters in various warfare scenarios stems from the fact that they provide a tactical advantage and option that is often used, from cargo lifting to urban warfare support.

This project will serve to provide a background study on past wars in terms of their fuel usage, and compare them to the metrics of modern day warfare. What is needed, and what will be answered here subsequently is that given various future warfare scenarios, how will helicopters be leveraged and used in those scenarios? The largest issue being fuel efficiency, the efficiency of helicopters from a tactical perspective as well as a design perspective will need to be applied to each of the future scenarios to provide feasibility guidance in the next 10 to 20 years of helicopter production by vendors, specifically Sikorsky.

In addition, alternate energy sources, where useful, must be leveraged in conjunction with liquid fuel use to alleviate the cost of using liquid fuel exclusively. The efficiencies in these various scenarios will inevitably affect the procurement and resulting revenue associated with the production and sale of helicopters in the coming decades.

1.3 Stakeholders

The following stakeholders are directly involved in the project outlined in this document:

1. Sikorsky - David Kingsbury
2. ILF Team- Hong Tran, Jessica Kaizar, Tariq Islam,
3. Dr. Laskey (Faculty Advisor) and SEOR Faculty

2 PRELIMINARY REQUIREMENTS

2.1 Task Organization

This project consists of technical and management tasks. The technical tasks will be assigned to team members according to their expertise. The management supporting tasks will be shared by all members. The project team members plan to collaborate closely to integrate individual efforts in delivering quality results within the project time-frame.

2.2 Data Collection

The ILF team will perform preliminary research to obtain data related to fuel consumption in past and current wars. Factors affecting the fuel consumption such as war scenario, environment, equipment used, types and sources of fuel will be collected and analyzed to define fuel-consumption metrics and baselines for the project. The following derived project requirements reflect the voices of the customer and the need for data collection required to initiate the project.

2.2.1 Background Research and Metrics

- Conduct analyses of fuel consumption of past wars
- Propose metrics associated with past-war fuel consumption
- Identify the fuel-consumption baselines based on the analyses of Desert Storm and OIF

3 TECHNICAL APPROACH

3.1 Past and Present Metrics

The ILF team will conduct analysis of the implication of liquid fuels in future warfare with an emphasis on rotary aircraft.

The ILF team will begin by surveying the use of energy in warfare throughout history. That information will be used to project future fuel usage in warfare and to choose or derive metrics to quantify the varying aspects of fuel consumption.

The ILF team will then establish a present day baseline for fuel consumption. A previous campaign operation with open source data such as OIF or Desert Storm will be used for the baseline. The forces in theater and their fuel consumption will be documented.

3.2 Scenarios

The ILF team will identify a range of representative war scenarios reflecting the use of rotary aircraft in warfare. Specifically, scenarios involving the Sikorsky Blackhawk/Seahawk and a heavy lift such as the Sikorsky CH-53D will be examined. Preliminary scenarios include:

- Attack/Assault
- Intelligence, surveillance, reconnaissance (ISR)
- Anti-submarine warfare (ASW)
- Heavy cargo lift
- Combat search and rescue (CSAR) / Medical evacuation (MEDEVAC)

Add in a smaller helicopter for an ISR scenario?
What about the CH-53E? 3 engines
Blackhawk is more midrange, CH-53D (2 engines) is heavier

Scenarios will encompass the range of mission areas and tactical situations (TACSIT) for rotary aircraft in the Army, Navy, and Marine Corps.

3.3 Technologies for Inspection: Alternate Energy Sources/ Rotorcraft Design

The ILF team will investigate alternate energies, the designs of hybrid engines and the overall designs of the rotary aircraft. Examples of these include air hybrid engines and coaxial rotary designs as used currently in the Sikorsky X2 prototype. Similarly, the changes in helicopter body and structural design will affect fuel consumption through aspects such as weight.

The following alternative energies and helicopter designs are being considered within the scope of this project.

Alternate Energies for Consideration:

- Regenerative braking (energy regeneration)
- Electricity
- Hydrogen fuel cells

Not sure about regenerative braking...

Alternate Helicopter Designs for Consideration:

- Air-hybrid engine [4]

- Helicopter Design with Diesel-Electric Hybrid Propulsion System--This hybrid propulsion system technology is developed by EADS Innovation Works. It consists of two two-stroke diesel engines, a pair of high-performance batteries and power electronics to control energy flows. EADS advertises that this propulsion system reduces fuel consumption and emission by 50%.[3]
- Structural design changes
    - Cargo room and weight
    - Coaxial rotor design [5]

Elaborate on these engine technology trends (this could be a big in our report)... the ultimate goal is more power, which usually lends itself to more towards increased fuel consumption.

How far have these engine designs come? Are any of them really feasible?

3.4 Cost Estimation

The ILF team will conduct a cost estimation to project the cost of fuel in the 2021 and 2031 timeframe. The point estimation will be used as the initial modeling input for fuel cost with the confidence interval to bound potential high and low fuel costs for comparison.

Trending cost estimation (error line, variable input)... capture a fairly large range
It's almost impossible to predict actual fuel prices

3.5 Modeling

The ILF team will develop a mathematical model of fuel consumption for each war scenario. The model will be excel based in order to easily manipulate variables for analysis. The model will collect key metrics measuring performance such as fuel consumption per mile, per hour, and per lift pound. Performance variables will include but not be limited to helicopter range, speed, and the cost of fuel. The model's other capability includes the generation of appropriate graphs and trending charts.

Upon establishing an executable mathematical model, the ILF team will take each alternate energy source and apply its effect on the measures of performance within the model. This will be done by converting fuel efficiency (e.g. gallons per minute) into units of energy (per fuel gallon), or joules, and applying that metric to the model to obtain the efficiency gain in terms of fuel reduction provided by the alternate energy source.

3.6 Analysis

The research conducted on the history of warfare fuel usage and the baseline scenarios will be used to examine fuel usage in the 2021 and 2031 time frames. In each time frame , the technologies identified for inspection will be evaluated against the baseline for changes, cost savings, tactical and operational implications.

In addition to examining additional technologies, the scenarios will be inspected and modified to reflect possible future warfare needs and tactics such as cyber warfare.

The role of rotary aircraft will be examined in the context of these future scenarios and the ILF team will conduct an analysis of the benefits of fuel efficiency with respect to cost savings, operational implications, the rising cost of fuel, and potential energy efficiencies.

4 EXPECTED RESULTS

4.1 Potential Cost-Savings

The ILF team will provide and analysis of the potential cost savings between fuel efficiencies, identified technologies and mission areas.

4.2 Executable Model

The ILF team will deliver to Sikorsky an executable model. This model will allow Sikorsky to extrapolate the relationships between the various input parameters, such as weight and fuel efficiency, into each of the future scenarios. It should be noted that due to the nature of researching future implications, this modeling is an estimated perspective.

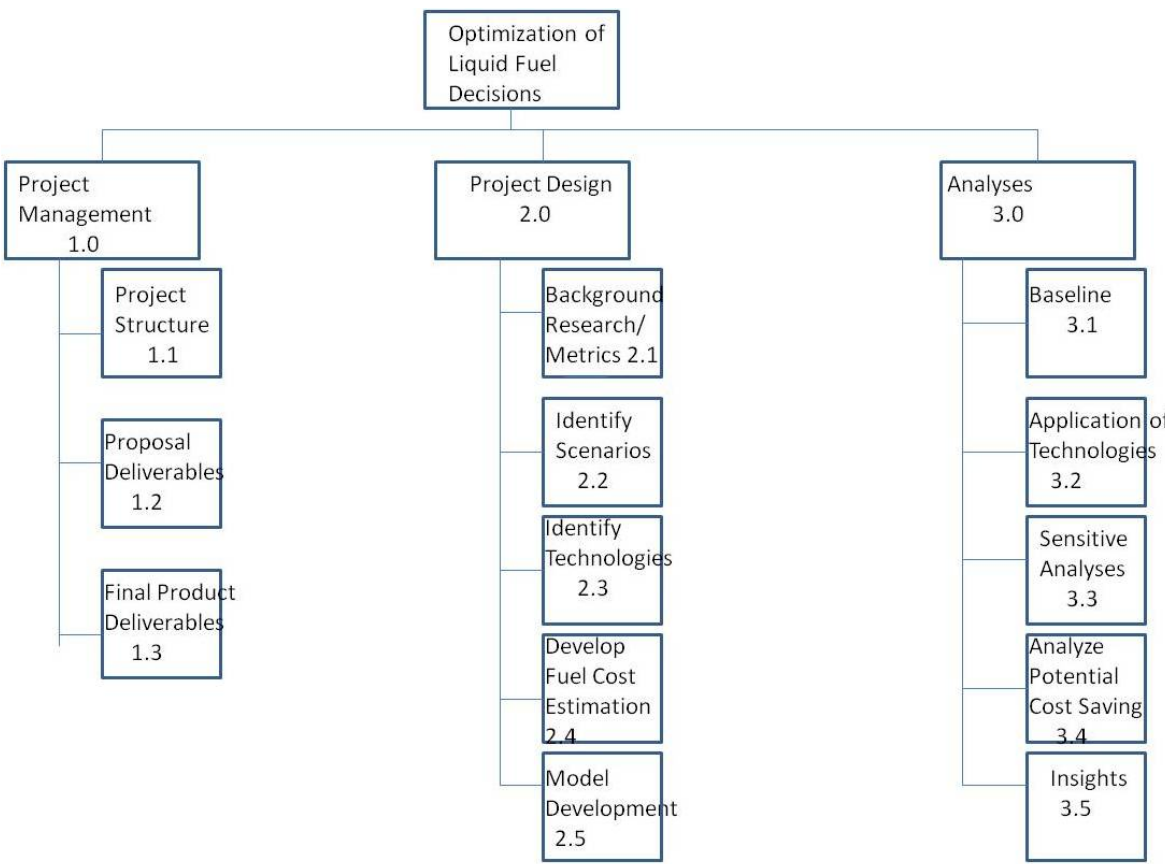
4.3 Insights and Recommendations

The ILF team will provide recommendations to be based upon each scenario and its parameters through the mathematical model. Recommendations will also be made upon the usage of alternate energy sources to be used in conjunction with liquid fuel in each scenario. These insights and recommendations shall be intended to influence near-future design decisions that affect fuel efficiency.

5 PROJECT PLAN

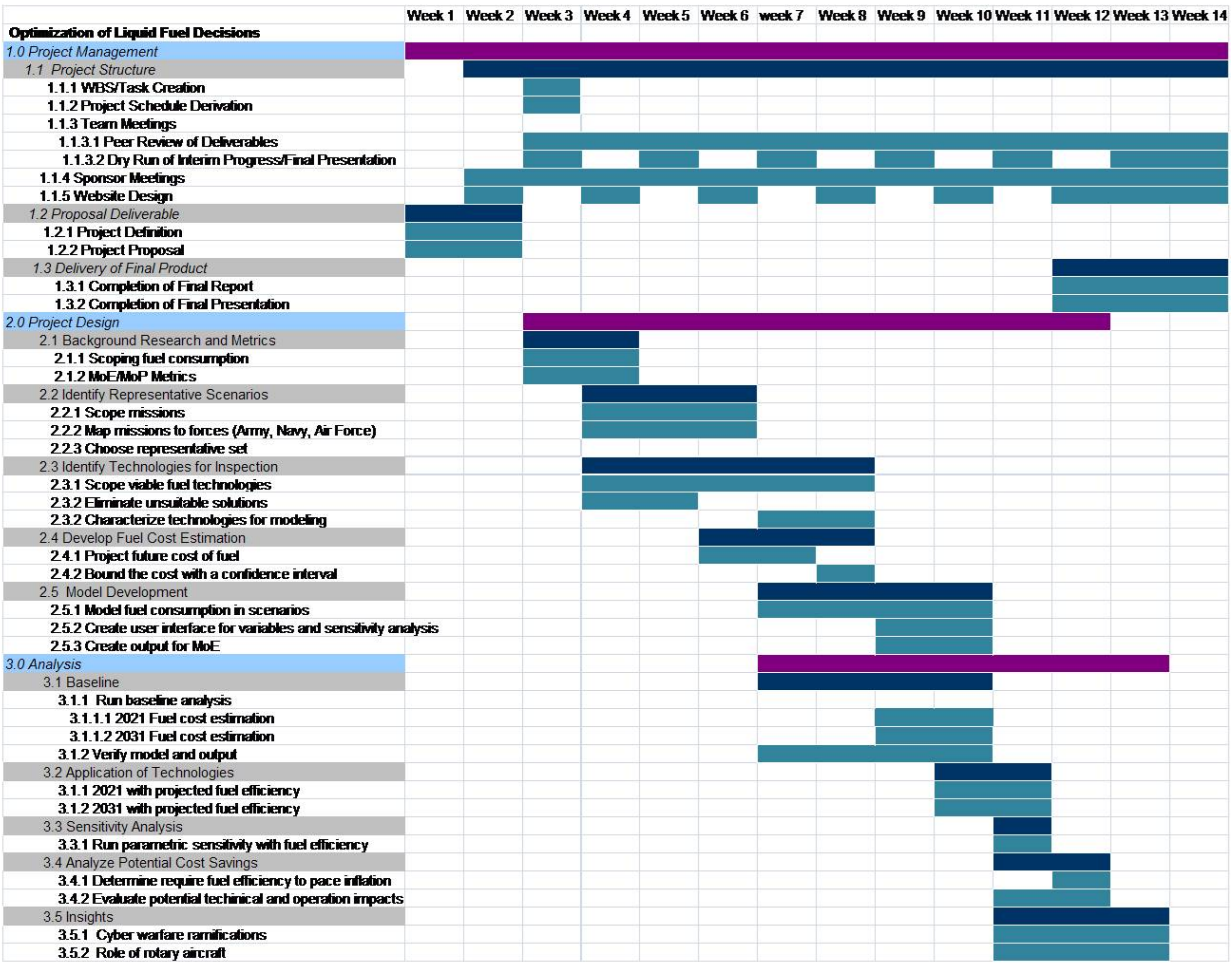
5.1 Work Breakdown Structure

The Work Breakdown Structure (WBS) is organized around the management and technical tasks. The Project Management WBS 1.0 collects effort related to the definition of the project structure, finalizing project proposal and the generation and completion of the final project deliverables. The remaining WBSs cover the technical effort relating to the implementation of the project design tasks, WBS 2.0 (performing background research and defining metrics, identifying scenarios and technologies, developing fuel cost estimation and developing model) and execution of various analyses, WBS 3.0 (baseline analyses to establish future fuel cost, model verification and validation, application of technologies, sensitive analysis, potential cost saving analysis and model modification to reflect cyber warfare and examination of rotor aircraft role against future warfare)



5.2 Project Schedule

The project tasks are scheduled throughout the 14-week semester and are based on an input of 10-hour per person per week. The scheduled tasks also represent the budgeted cost of work scheduled (BCWS) and are shown in the below figure. The project schedule reflects one-week buffer to cover the unexpected unknowns. The project team also builds another schedule to record the actual hours worked (ACWP) and earned value (credit taken) hours (BCWP). The team will take credit for the hours worked only if the results/milestones are achieved. This earned value method is known as the 0-100 technique.



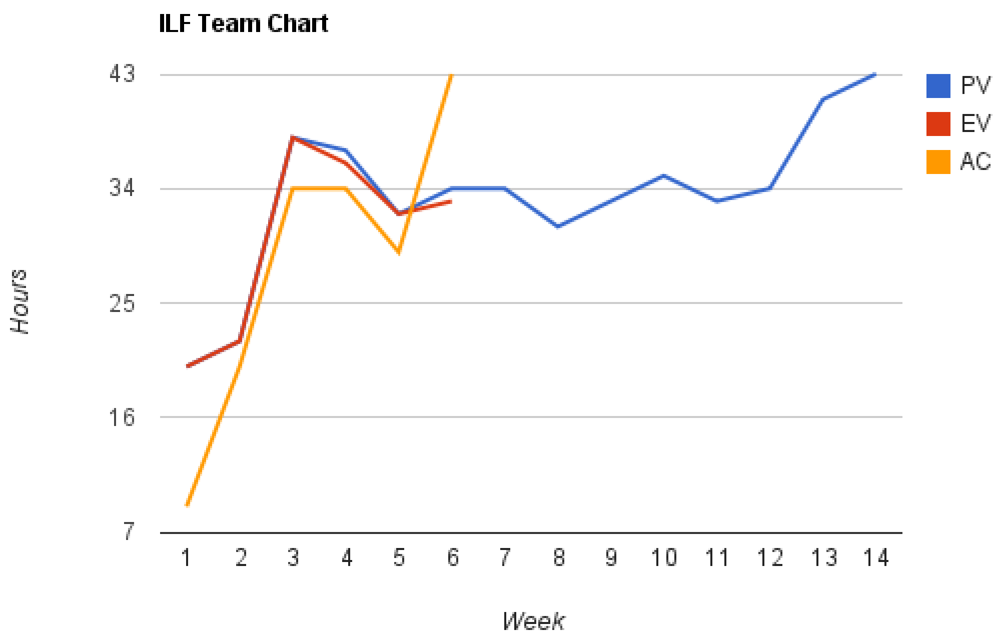
Below is an enlarged view of the various tasks and their organization from the above schedule diagram:

1.0 Project Management

1.1 Project Structure
1.1.1 WBS/Task Creation
1.1.2 Project Schedule Derivation
1.1.3 Team Meetings
1.1.3.1 Peer Review of Deliverables
1.1.3.2 Dry Run of Interim Progress/Final Presentation
1.1.4 Sponsor Meetings
1.1.5 Website Design
1.2 Proposal Deliverable
1.2.1 Project Definition
1.2.2 Project Proposal
1.3 Delivery of Final Product
1.3.1 Completion of Final Report
1.3.2 Completion of Final Presentation
2.0 Project Design
2.1 Background Research and Metrics
2.1.1 Scoping fuel consumption
2.1.2 MoE/MoP Metrics
2.2 Identify Representative Scenarios
2.2.1 Scope missions
2.2.2 Map missions to forces (Army, Navy, Air Force)
2.2.3 Choose representative set
2.3 Identify Technologies for Inspection
2.3.1 Scope viable fuel technologies
2.3.2 Eliminate unsuitable solutions

2.3.2 Characterize technologies for modeling
2.4 Develop Fuel Cost Estimation
2.4.1 Project future cost of fuel
2.4.2 Bound the cost with a confidence interval
2.5 Model Development
2.5.1 Model fuel consumption in scenarios
2.5.2 Create user interface for variables and sensitivity analysis
2.5.3 Create output for MoE
3.0 Analysis
3.1 Baseline
3.1.1 Run baseline analysis
3.1.1.1 2021 Fuel cost estimation
3.1.1.2 2031 Fuel cost estimation
3.1.2 Verify model and output
3.2 Application of Technologies
3.1.1 2021 with projected fuel efficiency
3.1.2 2031 with projected fuel efficiency
3.3 Sensitivity Analysis
3.3.1 Run parametric sensitivity with fuel efficiency
3.4 Analyze Potential Cost Savings
3.4.1 Determine require fuel efficiency to pace inflation
3.4.2 Evaluate potential techinical and operation impacts
3.5 Insights
3.5.1 Cyber warfare ramifications
3.5.2 Role of rotary aircraft

5.3 EVM Chart



5.4 Project Deliverables

The following deliverables are required of the ILF team. The last two deliverables are also requirements from the customers. All deliverables have been incorporated in the project schedule.

1. Project Proposal
2. Two Interim Briefings
3. A Spreadsheet File Documenting Modeling and Analyses Effort
4. Briefing that communicates work done and results
5. Written report that details analysis and rationale used

6 References

1. Sohbet Karbuz - US Military Oil Consumption - http://www.energybulletin.net/node/13199
2. www.globalsecurity.org
3. http://ila2010.eads.com/en.htm#innovation
4. http://www.gizmag.com/air-hybrid-vehicles-could-cut-fuel-consumption-in-half/17810/?utm_source=Gizmag+Subscribers&utm_campaign=258a43f045-UA-2235360-4&utm_medium=email
5. http://en.wikipedia.org/wiki/Sikorsky_X2