Two-Page Annotated Bibliography
(MAE 640)
Summarize

Reference Document Examined:	Frederick, R. A., Berg, P., and Loeblich, W., "Using CEQUEL for Thermochemistry Calculations in a Graduate Rocket Propulsion Course at UAH," UAH Propulsion Research Center
Reviewer:	Veronica Loomis
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Summary of Paper:

This paper explains how to use code for a solid-fuel ramjet design project which utilizes a spreadsheet and python code. This code (Chemical Equilibrium in Excel – CEQUEL) includes calculations for thermochemical properties, internal ballistics, and flight performance characteristics. It demonstrates this in both a spreadsheet and the python-based implementation. This saves time by eliminating the need to look up data in tables or try and fit data on parametric curves.

CEQUEL is available for Microsoft Excel to perform thermochemistry calculations. The user can use it to perform calculations of things such as temperature, enthalpy, entropy, pressure, rocket area ratio, and so on. This is done using either the Equilibrium Wizard or the Isobaric Mixing Wizard. These contain libraries of over 100 reactants to test.

Figure 1: Equilibrium Wizard - Reactant Input Example

CEQUEL is also available via python. It is suggested that one is familiar with the Excel version first, so it is clear what potential options are able to be chosen and in what format. A way to test the usefulness of CEQUEL was by recreating a figure from the textbook which detailed the performance of rocket propellant combinations. The results were almost identical except for a few cases of ~10% differences.

One big project was the evaluation of three missions: all-solids using two center-perforated grains, a baseline mission to work out bugs, and a design mission where each team did studies on the fuel candidates provided and changed input parameters within the guidelines to find a maximum range. The results concluded that the advantages of all-solids is the compact size, max

Mach number, and lower time to target compared to other missions. It was also found that the advantage of a ramjet is that the range increased to almost double that of the baseline mission.

B. Assess:

Important Facts from Document:

1. CEQUEL is a very helpful tool when trying to calculate thermochemical properties.
2. CEQUEL is available in both Excel and Python and it is recommended that one is comfortable with the Excel version first.
3. When comparing data from both versions CEQUEL, the results are very close to identical with a few exceptions for scaling issues.
4. The advantages for all-solid propellant include its compact size, maximum Mach number, and time to target.
5. One of the advantages of ramjets is the increase in range during a mission.
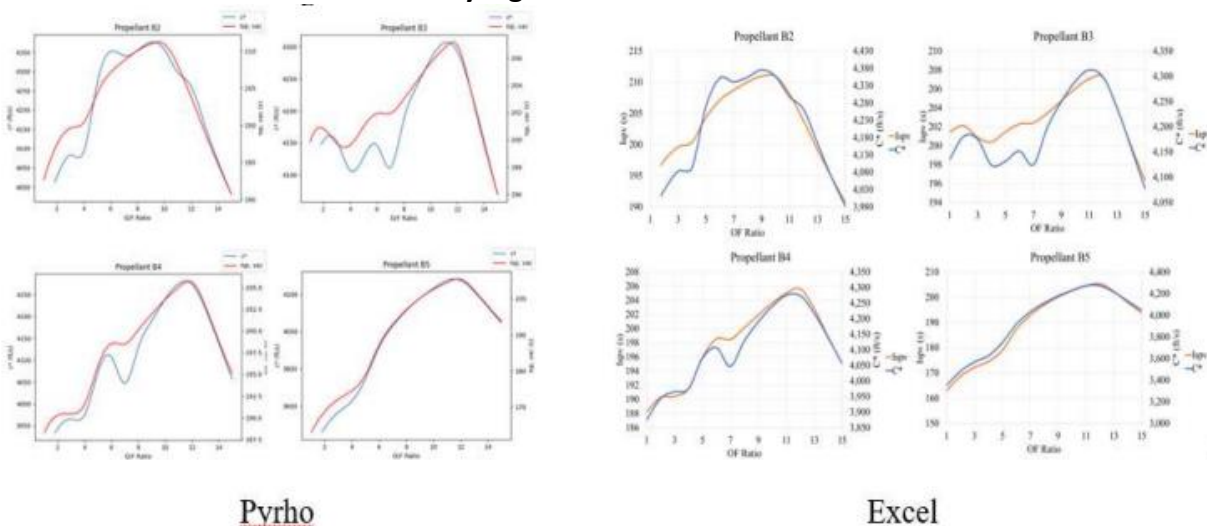
Key Figure from Document:

Figure 2: The results from the Python CEQUEL (left) compared to the Excel CEQUEL (right)

Important Relationships among Parameters Described in the Paper:

1. An increase in c* leads to an increase in specific impulse in a vacuum
2. The thrust of the rocket increases as the coefficient of thrust increases (which is when the nozzle area ratio decreases)

$$C_{f,i} = C_{fv,i} - \frac{P_a}{P_{C,i}} \varepsilon_i$$

C. Reflect

This paper was very helpful in getting a basic understanding of CEQUEL and what it can be used for. It lays out the different programs it can be used in as well as demonstrations of problems it has worked through. This will be helpful in this class to do the more difficult and rigorous calculations.