1 Understanding Specific Impulse (I_s)

Specific impulse is a measure of a rocket engine's efficiency and is defined as:

$$I_s = \frac{F}{\dot{m} g_0}$$

where:

- I_s is the specific impulse in seconds,
- F is the thrust (lbf),
- $\dot{m}$ is the propellant mass flow rate (lbm/s),
- g_0 is the standard gravitational acceleration (32.174 ft/s^2).

1.1 Why No g_0 for Sea-Level I_s?

The sea-level specific impulse in your code is calculated as:

$$I_s = \frac{I_t}{m_p} = \frac{F_t t_b}{m_p}$$

instead of the traditional form:

$$I_s = \frac{F_t}{\dot{m} g_0}$$

This formulation arises because:

1. **Implicit Definition via Total Impulse:** The total impulse I_t (thrust $\times$ burn time) is used to find I_s, avoiding the explicit use of g_0.
2. **Sea-Level Calculation Assumption:** The specific impulse at sea level can be directly derived from the burn-time-thrust relationship without needing to introduce the g_0 term.

1.2 Why is g_0 Used for Optimal and Vacuum I_s?

For the optimum expansion and vacuum conditions, the code switches to the standard definition:

$$I_s = \frac{F}{\dot{m} g_0}$$

This happens because:

1. **Conventional Definition of I_s:** In aerospace engineering, specific impulse is conventionally defined in terms of force per unit weight flow rate, requiring the division by g_0.

2. **Comparison Between Different Environments:** The use of g_0 ensures that specific impulse remains comparable across different conditions (sea level, optimum, and vacuum).

3. **Avoiding Unit Issues:** Since $\dot{m}$ is in pounds mass per second (lbm/s) and thrust is in pounds force (lbf), directly dividing them would yield inconsistent units. Including g_0 ensures that I_s is in seconds.