Bereshit’s Lunar Lander Summary Report

Landing Method Overview

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The spacecraft was landed on the Moon using a controlled descent strategy managed by a PID control system. The main goals were to reduce both vertical and horizontal velocities to safe landing values and maintain the optimal angle for stability and control, all while efficiently managing fuel consumption.

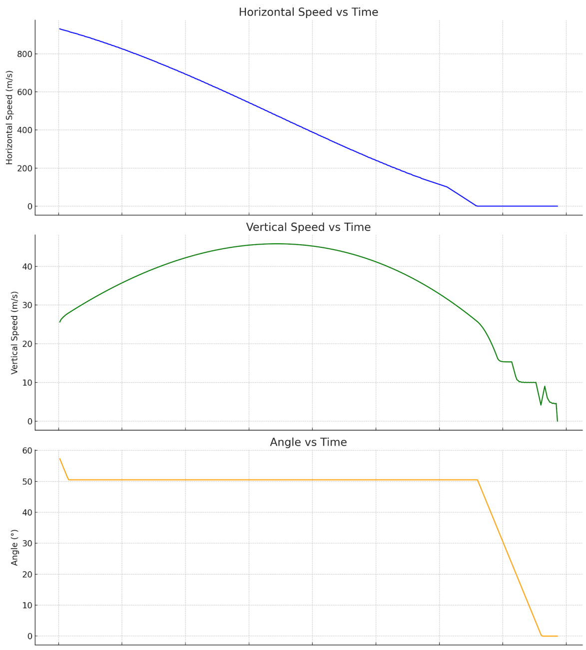
PID Control Mechanism

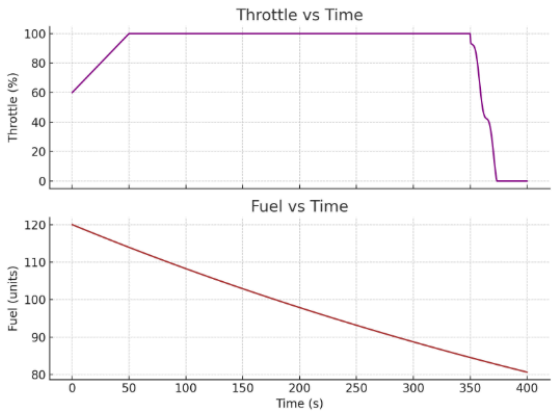
Each PID controller adjusts its output based on:

- **Proportional term (P)**: How far the current value is from the desired value.
- **Integral term (I)**: The sum of past errors to eliminate residual steady-state errors.
- **Derivative term (D)**: Predicts future error based on the rate of change.

These controllers allow smooth correction of the lander’s motion in real-time, ensuring a stable and safe descent.

Graph Interpretation





Horizontal Speed (Blue)

Behavior: The horizontal speed starts high (~930 m/s) and decreases steadily over time.
Influence: Controlled mainly by adjusting the lander's tilt (angle), which redirects some of the engine thrust to counteract horizontal motion.
Observation: As the angle reduces, more thrust is directed horizontally, slowing the lander’s lateral drift effectively.

Vertical Speed (Green)

Behavior: Starts at a moderate descent speed (~25 m/s) and gradually increases due to gravity, but is later slowed and stabilized by increased throttle.
Influence: Managed directly by the engine's throttle using the vertical PID controller.
Observation: The descent rate is controlled to ensure a soft landing. Throttle spikes indicate periods where the PID compensates for increased descent velocity.

Angle (Orange)

Behavior: Starts at a steep angle (~57°) and steadily decreases to 0° as the lander approaches touchdown.
Influence: Managed by the PID controlling horizontal speed (dhs). As horizontal speed decreases, the angle is gradually corrected to vertical (0°).
Observation: Smooth transition in angle shows stable PID tuning, crucial for ensuring the lander is upright upon landing.

Throttle (Purple)

Behavior: Throttle begins at a moderately high value (~60%), quickly ramps up to full thrust (100%), remains steady during the main descent phase, and then rapidly drops to 0% with oscillations near the end.
Influence: Controlled by the **vertical PID controller**, which regulates descent speed. In early stages, high throttle is required to counteract gravity. As the lander stabilizes and nears the surface, less thrust is needed, triggering a controlled shutdown of the engine.
Observation: The sharp increase in throttle ensures enough lift to slow vertical descent. The steady 100% plateau shows consistent control during the main burn. Near landing, the noisy throttle drop suggests active PID corrections in response to small altitude and speed deviations, ensuring a smooth final approach.

Fuel (Brown)

Behavior: Fuel depletes continuously from 120 units to ~20 units in a smooth, concave-downward (slightly curved) trajectory—slightly slowing in consumption over time.
Influence: Directly tied to **throttle usage**—higher throttle burns more fuel. As throttle drops near the end, the rate of fuel consumption slows accordingly, resulting in the curved shape.
Observation: The slight curvature reflects efficient throttle management—most fuel is used

during the full-throttle descent phase, with reduced burn as the lander nears touchdown. The gradual tapering ensures no excessive fuel use late in the landing sequence, helping to preserve reserves.

Code Summary

The simulation code included:

- State variables tracking position, velocity, angle, fuel, etc.
- PID controllers that compute throttle and angle adjustments.
- Physics update step that computes the lander's new state based on thrust, gravity, and orientation.
- A data logger saving time-step results for later analysis.