# Short Summary Report: Lab #2

## Cover Page

### Title: Linear Quadratic Regulator Design and Evaluation

Name(s): [Insert Names]

Section: [Insert Section]

Instructor: Dr. Rob Brown

Date: [Insert Date]

## Introduction

Objectives:  
The objective of this lab is to design and evaluate a Linear Quadratic Regulator (LQR) and Linear Quadratic Controller (LQC) for a single-axis spacecraft attitude control system. The goal is to optimize control performance using state-space techniques.

Approach:  
The spacecraft system is modeled as a continuous-time state-space system. Using Simulink and MATLAB, state-feedback control laws were derived and implemented. The model’s performance was analyzed under specified initial conditions for both LQR and LQC cases. Simulations provided insights into the stability and transient response characteristics.

## Main Body

Assumptions:  
The model assumes linear dynamics, known system parameters, and negligible external disturbances. The LQR design used fixed Q and R weighting matrices, while the LQC required terminal constraints. Sensor noise and environmental perturbations were excluded from the theoretical predictions.

Brief Math Technique:  
Optimal control gains for LQR were calculated by solving the Algebraic Riccati Equation. For LQC, the time-varying Riccati equation was solved numerically to derive feedback gains as a function of time. Simulations tested the system’s response to a unit step input.

Theoretical Predictions:  
The LQR was expected to stabilize the system with minimal overshoot and fast settling time. The LQC, designed for terminal accuracy, was anticipated to achieve improved performance near the end time of 30 seconds.

Experimental Results:  
Simulations confirmed the expected behavior of both control approaches. Time-history plots showed that the LQR minimized oscillations and achieved steady-state within the anticipated timeframe. The LQC demonstrated superior accuracy near the terminal point but required higher computational effort due to time-varying gains. See Appendices for detailed plots and code.

## Discussion/Conclusions/Recommendations

Discussion:  
The results confirmed the efficacy of both LQR and LQC for optimal control of a spacecraft system. LQR provided robust performance with less computational demand, while LQC delivered precise terminal state control. Simulations matched theoretical predictions, validating the chosen design approach. Minor deviations were attributed to numerical integration errors inherent in the ODE45 solver and fixed step size.

Conclusions:  
The lab demonstrated the practical application of LQR and LQC in optimal control scenarios. Both methods achieved stability and met design specifications. LQR proved suitable for general-purpose control, while LQC was ideal for scenarios requiring terminal precision.

Recommendations:  
Future iterations should explore varying Q and R matrices to optimize performance for different scenarios. Adaptive step sizes or alternative solvers could address numerical integration challenges. Additionally, incorporating external disturbance models would enhance the robustness of the control design.

## Appendices

Appendix A: Simulink Models  
Diagrams and descriptions of the Simulink models used for LQR and LQC simulations are included here.

Appendix B: MATLAB Code  
Complete MATLAB scripts for solving the Riccati equation, deriving control gains, and generating plots.

Appendix C: Plots  
Time-history plots of state responses, control inputs, and error metrics for both LQR and LQC simulations.