# AE 6531: Aerospace Robust Control I

**Catalog Description:** AE 6531: Aerospace Robust Control I. 3-0-3.
Robustness issues in controller analysis and design. LQ analysis, H2 norm, LQR, LQG, uncertainty modeling, small gain theorem, $H_\infty$ performance, and the mixed-norm $H_2/H_\infty$ problem.

**Coordinator:** Wassim Haddad, Associate Professor

**Course Objective:** To provide students with an advanced treatment of linear robust control as applied to aerospace systems.

**Prerequisites:**
1) A course in classical control theory.
2) A course in linear systems, state space models and matrix theory.

**Recommended Textbooks:**

1. D. S. Bernstein and W.M. Haddad, *Multivariable Control-System Synthesis: The Fixed-Structure Approach*, preprint.
2. B.D.O. Anderson and J. B. Moore, *Optimal Control-Linear Quadraic Methods,* Prentice Hall, Englewood Cliffs, NJ, 1990.
3. H. Kwakernaak and R. Íivan, *Linear Optimal Control Systems,* Wiley, New York, 1972.
4. K. Zhou, J.C. Doyle, and K. Glover, *Robust and Optimal Control,* Prentice Hall, New Jersey, 1996.
5. J.M. Maciejowski, *Multivariable Feedback Design*, Addison-Wesley, Reading, MA,1989.

**Topics**

An Introduction to Matrix Theory
- Matrix Operations
- Matrix Decompositions (Jordan, Schur, Singular Value)
- Nonnegative, Positive Definite Matrices
- Matrix Norms, Generalized Inverses
- Kronecker Calculus, The Matrix Exponential

Linear System Theory
- Controllability, Observability, Stabilizability, Detectability
- Lyapunov Functions, Lyapunov Equations
- $H_2$Norm: Deterministic Formulation
- $H_2$ Norm: Stochastic Formulation
- Matrix Differentials and Optimization Theory

Fixed-Structure Filter and Controller Synthesis
- The Standard Problem
- The Linear-Quadratic Regulator Problem (LQR)
- Analysis of the Algebraic Riccati Equation
- Static Output Feedback Controllers
- Least Squares Estimation Theory
- The Kalman Filter and The Observer Riccati Equation
- The Linear-Quadratic-Gaussian Problem (LQG)
- Full-Order Dynamic Compensation and the Separation Principle
- PI Control, Model Following

Frequency Domain Concepts
- Frequency Domain Properties of the LQR and LQG Problems
- Guarantees of Phase and Gain Margins
- The Return Difference Equality

Robust Stability and Performance

- The $H_\infty$ Norm
- $H_\infty$ Performance Measure
- Internal Stability
- The Multivariable Nyquist Criterion
- Sensitivity/Complementary Sensitivity
- MIMO Performance Specifications
- Nominal Performance
- Robust Performance
- The Small Gain Theorem

The Complex Structured Singular Value

- Necessary and Sufficient Conditions for Robust Stability
- μ-Analysis

**Computers:** Several assignments will require computations using MATLAB, Control System Toolbox, and the μ-Toolbox.