Title: Linear Algebra and Estimation Theory **Hours:** 30 (3.0 CEUs)

Delivery: Live-remote, 90-minute lectures twice a week for 10 weeks **Start:** January 7, 2025

Linear Algebra and Estimation Theory is a fundamental part of the Communications Systems Engineering Certificate (CSEC) program for NGC. This course covers foundational concepts in linear algebra as they relate to estimation techniques. This course equips participants with the mathematical tools necessary for applications in signal processing, communications, and data analysis. Participants will delve into essential topics such as random vectors, covariance matrices, linear transformations, and Gaussian random variables. Through interactive exercises and real-world examples, students will gain practical insights into the analytical frameworks critical to engineering and applied sciences.

Program Experience

This intensive program spans 10 weeks (Tuesday/Thursday evenings), with a combination of theoretical lectures and hands-on problem-solving exercises. Participants will engage with a wide array of topics in linear algebra and estimation, focusing on practical applications in data-driven environments. The course structure emphasizes the importance of matrix operations, vector spaces, and probability distributions in creating efficient estimators. By the end of the course, participants will possess a comprehensive understanding of the principles and applications of linear transformations and random vector analysis, foundational to advanced study and professional work in engineering and technology.

Benefits:

- Master the principles of vector spaces, matrices, and linear transformations
- Understand and apply the properties of random vectors and covariance matrices
- Derive and utilize correlation and cross-correlation matrices in data analysis
- Perform linear transformations and interpret their effects on data
- Apply the Central Limit Theorem and Law of Large Numbers in estimation contexts
- Calculate and interpret expectations, variances, and covariance for multivariable functions
- Design and evaluate linear estimators using minimum mean square error (MMSE) techniques
- Develop analytical skills for practical applications in signal processing and communications

Topics:

- Introduction to Random Processes and Estimation Theory
  - Definition and applications of random processes
  - Overview of key estimation techniques in engineering
- Random Vectors and Matrices
  - Defining and understanding random vectors
  - Properties of vectors in multi-dimensional space
  - Calculation and interpretation of mean vectors
- Covariance and Correlation Matrices
  - Definitions and properties of covariance and correlation matrices
  - Hermitian symmetric matrices and their importance
  - Non-negative definite matrices
- Linear Transformations
  - Transforming random vectors with linear functions
  - Applications of transformations in engineering analysis
  - Mean and covariance of transformed vectors
- Gaussian Random Variables and Vectors
  - Properties of Gaussian distributions

  - Gaussian vectors and their application in real-world problems
  - Introduction to characteristic functions and Fourier transforms
- Law of Large Numbers and Central Limit Theorem
  - Application of the Law of Large Numbers in estimation
  - Central Limit Theorem and its implications for data distributions
  - Examples and exercises in convergence and normality
- Least Squares Estimation and Optimization
  - Principles of least squares and linear estimators
  - Calculation of best linear unbiased estimators
  - Hands-on exercises with linear optimization problems
- Applications in Signal Processing and Communications
  - Practical applications of estimation theory in engineering
  - Case studies in signal processing
  - Final project: Design a simple estimation model using real-world data