M. Tech. in Aerospace Engineering (Guided Missiles)

Semester I

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	AM 607	Mathematics for Engineers	3	1	4
2	AE 601	Aerospace Propulsion	3	1	4
3	AE 602	Aerodynamics	3	1	4
4	AE 603	Navigation, Guidance & Control	3	1	4
5	AE 604	Aerospace Structures	3	1	4
6	AE 605	Flight Mechanics	3	1	4
		Total	**18**	**6**	**24**

Semester II

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	AE 606	Flight Instrumentation	3	1	4
2	AE 607	Missile Propulsion	3	1	4
3		Elective – I [From Department]	3	1	4
4		Elective – II [From Department]	3	1	4
5		Elective – III	3	1	4
6		Elective – IV	3	1	4
		Total	**18**	**6**	**24**

Note: 04 weeks Practice school during summer vacation for scholarship students.

Semester III

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
3	AE 651	M.Tech. Dissertation Phase I	28**		14
		Total	**28**		**14**

Semester IV

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	AE 652	M.Tech. Dissertation Phase II	28**		14
		Total	**28**		**14**

****Contact Hours/week**

List of Electives

Sl. No.	Course Code	Course
1	AE 608	UAV Design
2	AE 609	Guidance & Control for Aerospace Vehicles
3	AE 610	Missile Guidance & Control
4	AE 611	UAV Guidance & Control
5	AE 612	Experimental Aerodynamics
6	AE 613	Computational Aerodynamics
7	AE 614	Structural Dynamics and Aero-elasticity
8	AE 615	Estimation and Tracking for Aerospace Applications
9	AE 616	Nonlinear and Robust Control
10	AE 617	Avionics
11	AE 618	Signals and Systems
12	AE 619	Robotic Path Planning and Control
13	AE 620	Optimal Control with Aerospace Applications
14	AE 621	Advanced Missile Guidance
15	AE 622	Ducted Rocket & Combustion
16	AFW 601	Ballistics of Bombs & Projectiles
17	AFW 602	Design of Air Armament - I
18	AFW 603	Airborne Weapon System Effectiveness
19	AFW 604	Warhead Design and Mechanics
20	AFW 605	Air Armaments Control and Guidance
21	AFW 606	Design of Air Armament - II

22	AFW 607	Testing and Certification of Air Armament Stores
23	AFW 608	Fire Control Systems
		Open electives from other Departments

AE 601 Aerospace Propulsion

Introduction: Classification & mode of operation of various Propulsion Systems.

Basic Thermodynamics & Fluid Dynamics: Thermodynamic Laws, Conservation laws for mass, momentum and energy, Thrust Equation, Compressible flow, Isentropic Relations, Normal & Oblique Shock Waves, Quasi One-Dimensional flow through variable area ducts, Flow with Friction and Heat Transfer.

Gas Turbine Engine: Parametric Analysis of Ideal Turbojet, Turbofan & Turboprop engine, Specific Fuel Consumption, Propulsive, Thermal & Overall Efficiency, Component Performance (Subsonic & Supersonic Inlets, Axial and Centrifugal Compressors, Combustor, Turbine & Nozzle)

Piston Engines: Cycle Analysis, Engine Components and Classification, Engine Systems (Fuel Injection, Ignition, Lubrication, Supercharging, Inter Cooling)

Propellers: Classical Momentum Theory, Blade Element Theory, Variable Speed Propeller, Propeller Charts, Performance Selection & Matching, Ducted Propellers.

UAV Propulsion: Electric Motors, Solar Cells, Advanced Batteries, Fuel Cells, Future Technology.

References

1. Saeed Farokhi , "Aircraft Propulsion" 2nd Edition, Wiley
2. Jack L. Kerrebrock, "Aircraft Engines & Gas Turbines" 2nd Edition, MIT Press
3. J. Mattingly & H. von Ohain, "Elements of Propulsion: Gas Turbines & Rockets" AIAA Education,
4. Philip Hill & Carl Peterson, "Mechanics and Thermodynamics of Propulsion" 2nd Edition, Prentice Hll
5. Gordon C Oates, "Aerothermodynamics of Gas Turbine and Rocket Propulsion" 3rd Edition, AIAA Education,
6. Maurice J Zucrow , "Aircraft and Missile Propulsion", Vol 1 & 2, Wiley

AE 602 Aerodynamics

Introduction, Governing equations, Flow kinematics, Elementary flows, Non-lifting and lifting flows, Flow over airfoils; Kutta-Joukowski theorem, Kutta conditon, Kelvin's theorem, Thin airfoil theory; Flow over wings; Prandtl's lifting line theory; Viscous fluid flow, Turbulent flow, flow separation, Boundary layer.

Governing equations for compressible fluid flow; Normal shock waves, Oblique shock and expansion waves, Prandtl-Mayer waves, Shock-Expansion Theory. Flow over supersonic airfoils and wings; Shock Wave – Boundary Layer interactions.

Introduction to hypersonic flow.

Aerodynamic characteristics of aerospace vehicles.

Introduction to experimental aerodynamics.

Text/References:

1. John D. Anderson, Fundamentals of Aerodynamics, 4th Edition, McGraw Hill, 2006.
2. E. L. Houghton and P. W. Carpenter, Aerodynamics for Engineering Students, 5th Edition, Butterworth-Heineman, Oxford, 2003.
3. John D. Anderson, Introduction to flight, 5th Edition, McGraw Hill, 2005.
4. F. M. White, Viscous Fluid Flow, McGraw Hill, 2006.
5. F. M. White, Fluid Mechanics, McGraw Hill, 2003.
6. Fox and MacDonald, Introduction to Fluid Mechanics, 5th Edition, John Wiley & Sons, inc, 2003.
7. John D. Anderson, Modern Compressible Flow: With Historical Perspective, 3rd Ed, McGraw Hill, 2004.
8. John D. Anderson, Hypersonic and High Temperature Gas Dynamics, McGraw Hill, 2006.
9. Maurice Rasmussen, Hypersonic Flow, John Wiley & Sons, inc, 1994.
10. S. S. Chin, Missile Configuration Design, McGraw Hill, 1961.
11. Michael R. Mendenhall**,** Tactical Missile Aerodynamics,2nd Ed., AIAA Publications, 1992.
12. Reg Austin, Unmanned aircraft Systems: Uavs design, development and deployment, John Wiley & Sons, inc, 2010.

AE 603 Navigation, Guidance & Control

Navigation: Navigation systems and principles of operation, Continuous waves and frequency modulated radars, MTI and Doppler radars; types of navigation; ILS, Optical landing, VOR, INS, and GPS.

Guidance: Classification and phases of missile guidance. Guidance laws: pursuit, LOS, CLOS, BR and PN laws. Advance Guidance Systems such as Imaging, Scene Correlation, Millimeteric wave, Non-LOS Guidance Systems, Laser Based Guidance Systems.

Control: Classical linear time invariant control systems, transfer function representations, stability, Time domain characteristics, Frequency domain characteristics, Root Locus, Nyquist and Bode plots, Introduction to state space analysis.

Texts/References:

1. Ching Fang Lin, Modern Navigation, Guidance and Control Processing, Prentice Hall, 1991
2. P. Zarchan, Tactical & Strategic Missile Guidance, American Institute of Aeronautics and Astronautics, 2007
3. G. M. Siouris, Missile Guidance and Control Systems, Springer, 2004
4. John H. Blakelock, Automatic Control of Aircraft and Missiles, Wiley, 1991
5. Anthony Lawrence, Modern Inertial Technology, Springer, 1998
   K. Ogata, Modern Control Engineering, Prentice Hall of India, 1995.

AE 604 Aerospace Structures

Review of Strength of Materials.

Introduction to Aerospace Materials – Metal Alloys and Fiber Reinforced Composite.

Introduction to different types of constructions: Monocoque, Semi-Monocoque, Truss, and Corrugated shell.

Introduction to Aircraft and Missile Structural Components: Spars; Ribs; Stringer; Longerons.

Analysis of stress; Analysis of strain.

Material Constitutive Relations; Analysis of pressure vessels; Bending, Shear and torsion of thin-walled members; Buckling of Columns; Failure Theories;

Introduction to Vibration and Fatigue.

Texts/ References:

1. David J. Peery, Aircraft Structures, Dover Publications, 2011
2. E. F. Bruhn, Analysis and Design of Flight Vehicle Structures, S.R. Jacobs, 1973
3. T. H. G. Megson, Aircraft Structures for Engineering Students, Butterworth-Heinemann, 2010.
4. G. F. Titterton, Aircraft Materials and Processes, Himalayan Books, 2013.

AE 605 Flight Mechanics

Flight Performance: Standard Atmosphere. Aerodynamics of airfoils and wings. Brief history of flight. Introduction to performance. Equations of motion. Thrust required, thrust available & maximum velocity for level un-accelerated flight. Power required, power available and max. velocity. Altitude effects on power required and available. Rate of climb. Gliding Flight. Absolute ceiling. Time to climb. Range and Endurance. Takeoff and Landing performance. Turning Flight and v-n diagram.

Flight Stability and Control: Definition of stability and control: static stability, dynamic stability, control, the partial derivative. Moments on missile, absolute angle of attack, Criteria for longitudinal static stability. Contribution of wings to moment about center of gravity, Contribution of tail to moment about center of gravity.Total pitching moment about center of gravity. Equations for longitudinal static stability. The neutral point. The static margin. Aerodynamic derivatives. Cross coupling. The concept of static longitudinal control. Lateral stability: Induced rolling moments, Various configurations. Aerodynamic damping. Stability margins. Control forces and moments.

Text/References:

1. B. Etkin, Dynamics of Atmospheric Flight, Dover, 2005 .
2. Robert C. Nelson, Flight Stability and automatic control, Tata McGraw-Hill, New Delhi, 2007

3. Bandu N. Pamadi, Performance, Stability, Dynamics and control of airplanes. AIAA Educational Series.
4. John D Anderson, JR, Introduction to Flight, Tata McGraw-Hill, New Delhi.

Suggested References:

1. Michael R. Mendenhall**,** Tactical Missile Aerodynamics, , 2nd Ed., AIAA Publications, 1992.
2. Eugene L. Fleeman, Missile Design and System Engineering, AIAA Education Series, 2012.
3. J.J. Jerger, System Preliminary Design, D. Van Nostrand Co., Inc., Princeton, New Jersey, 1960.
4. A.E. Puckett and Simon Ramo, Guided Missile Engineering, McGraw Hill, 1989.

AE 606 Flight Instrumentation

Basic concepts of measurements: Generalized characteristics of sensors, instruments, and measurement systems. Measurement of physical quantities such as pressure, force, altitude, temperature, flow, strain and vibration, and angle of attack. Inertial sensors: gyroscope and accelerometer with recent advancements therein.

Signal processing: Operational amplifiers, instrumentation and Charge amplifiers. Analog to digital and digital to analog converters. Data acquisition system.

Data transmission: Signal transmission by analog and digital means, methods of modulation and demodulation, multiplexing time division and frequency division, telemetry systems and trajectory tracking devices such as Electro-optic tracking systems.

Tracking and data fusion: Thermal imagining system, scanning techniques, detectors and range analysis and multi sensor data fusion for trajectory analysis.

Texts/References:

1. E.O. Doebelin, Measurement Systems: Application and Design, 4thEd, McGraw Hill International, New York, 1990
2. J.M. Lloyd, Thermal imaging system, Plenum Pub., New York, 1975
3. D. Patranabis, Telemetry Principles, Tata McGraw Hill, New York, 2000.

AE 607 Missile Propulsion

Introduction: Classification and characteristics of various propulsive devices used for Missiles & Weapon Systems.

Thermodynamic Cycle Analysis: Engine cycles (Turbojet, Turbofan, Pulsejet, Ramjet and Rocket Engine). Thrust equation, specific impulse & fuel consumption. Thermal efficiency, propulsive efficiency & overall efficiency of propulsion systems.

Gas Dynamics: Equation of state, internal energy, enthalpy & entropy of an ideal gas. Laws of conservation of mass, momentum and energy. Wave equation and velocity of sound. Quasi one-dimensional gas flows. Characteristic parameters. Methods of solving one-dimensional problem of gas dynamics. Flow across Shock waves and Expansion waves. Flow through variable area ducts.

Reacting Flows & Heat Transfer: Reactant and product mixtures, stoichiometry, absolute enthalpy, enthalpy of formation, chemical equilibrium, Gibbs function, Adiabatic Flame Temperature, shifting equilibrium and frozen flow assumptions. One-dimensional flows with friction and heat transfer. Conduction, convection & radiation heat transfer processes in one-dimensional gas flows.

Chemical Rockets: Gravity free flight of rockets. Performance Parameters (Total & Specific Impulse, Thrust Coefficient, Characteristic Velocity, Effective Exhaust Velocity, Combustion Parameter, Characteristic Length, Residence Time). Methods for evaluating performance parameters. Evaluation of chemical composition of combustion products and chamber temperature. Introduction to Solid and Liquid Propellants.

Solid Rocket Motor: Solid propellant burning mechanism and combustion models. Burning rate of solid propellants under steady-state and transient conditions. Calculation of equilibrium chamber pressure under steady-state and transient conditions. Burning surface evolution. Erosive burning. Heat transfer and chamber wall temperature. Grain ignition and igniter assembly. Stability condition for steady-state operation of solid rocket motor. Combustion instability and frequency of acoustic pressure oscillations in the motor.

Liquid Rocket Engine: Burning mechanism of liquid propellants. Combustion of mono & bi propellant systems. Droplet vaporization combustion model. Ignition delay. Pressure transients in liquid rocket motors. Combustion Instability. Heat transfer and cooling. Design of liquid propellant engines (Propellant feed systems, Propellant tanks, Tank pressurization, Turbopumps, Engine integration)

Hypersonic Air Breathing Propulsion: Aerothermodynamics of Ramjet & Scramjet Engines, Performance Measures, Compression, Expansion and Combustion systems.

Text/References:

1. George P. Sutton, Rocket Propulsion Elements, Wiley-Interscience; 7th edition, 2000
2. M. J. Zucrow, Aircraft and Missile Propulsion, vol 1& 2, John Wiley, 1958
3. M. Barrere, Rocket Propulsion, Elsevier Pub. Co., 1960
4. M. J. Zucrow, Gas Dynamics, John Wiley & Sons; Volume 1, 1976
5. James E. A. John, Gas Dynamics, Prentice Hall, 3rd edition, 2006
6. P. Hill & C. Peterson, Mechanics & Thermodynamics of Propulsion, Prentice Hall, 2nd edition,1991
7. G. C. Oates, Aerothermodynamics of Gas Turbines and Rocket Propulsion, AIAA Education Series, 1989
8. W. Heiser, D. Pratt, D. Daley, U. Mehta, Hypersonic Airbreathing Propulsion, AIAA Education Series, 1994

AE 608 UAV Design

Terminology. Requirements. Certification approaches: aircrafts and UAVs. Airworthiness of aircrafts and UAVs. Airsafety issues. Handling qualities. Maneuverability requirements.

Aircraft design; UAV system design. UAV system identification. UAV project life cycles. Stages of Aircraft design. Initial sizing: aircrafts and of UAVs. UAV aerodynamics, structures and propulsion. Ground control systems. Ground and flight testing of UAVs. UAV guidance and Navigation. Design for reliability.

Introduction to UAV system Development.

Text books:

1. Daniel P. Raymer, Aircraft Design: A Conceptual Approach. AIAA Education Series, 2012
2. J. Jayaraman, Unmanned Aircraft Systems: A Global View, DRDO, 2014.
3. Reg Austin, Unmanned Aircraft Systems, Wiley Publication, 2010.
4. Eugene L. Fleeman, Missile Design and System Engineering, AIAA Foundation Series, 2014.
5. John Anderson Jr., Aircraft Performance & Design, McGraw-Hill2014.

AE 609 Guidance & Control for Aerospace Vehicles

Mathematical Modelling: Rigid body force and moment equations, Aerodynamics forces and moments representation, linearization, Transfer function generation and stability analysis.

Control: Aerodynamic and thrust vector control, polar and Cartesian control classical approach to control/ Autopilot design such as successive loop closer, three axes autopilot longitudinal, lateral and directional, three loop auto pilot and roll, lateral autopilot. Modern methods using state space approach, Controllability and Observability. Pole Placement techniques. Introduction to structure control interaction.

Servo Systems: Hydraulic, Pneumatic & electromechanical

Guidance: Missile & UAV guidance, Optimal guidance, Comparative study of PN guidance techniques, guidance laws for UAVs, path following, vision-based guidance, interception and avoidance; Collision detection and avoidance strategies. Introduction to cooperative control. Inertial Guidance: Intro, Inertial sensor, coordinate systems and transformations, Schuler tuning and gimbaled platform systems. INS – GPS integration, Data fusion.

Text/References:

1. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, New Delhi, 2001.
2. P Zarchan, Tactical and Strategic Missile Guidance, Vol 199 of Progress in Astronautics and Aeronautics, AIAA, Reston, VA, 2002.
3. P. Garnell, Guided Weapon Control Systems, 2nd Ed, Pergamon Press, London, 1980.
4. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, New York, 2004.
5. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.
6. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.
7. Amitava Bose, Somnath Puri, Paritosh Banerjee**,** Modern Inertial Sensors and Systems, Prentice-Hall of India, 2008.
8. Ian Moir, Allan Seabridge, Malcolm Jukes, Military Avionics Systems, Wiley, 2006.
9. Jay Gundlach, Designing Unmanned Aircraft Systems: A comprehensive Approach, AIAA Education Series, AIAA, 2012.
10. Rafael Yanushevsky, Guidance of Unmanned Aerial Vehicles, CRC Press, 2011.
11. Randal W. Beard and Timothy W. McLain, Small Unmanned Aircraft Theory & Practice, Princeton University Press, 2012.
12. N. V. Kadam, Practical design of flight control systems for launch vehicles and missiles, Allied Publishers, 2009
13. Rasmussen, S., and Shima, T. (Eds.), UAV Cooperative Decision and Control: Challenges and Practical Approaches, SIAM Publications, 2008.

AE 610 Missile Guidance & Control

Missile Kinematics: Kinematics of various courses, time of flight, lateral acceleration demand and turning rate spectrum for each case.

Guidance Laws: Optimal guidance, Advanced PN guidance laws, comparative study of different guidance schemes.

Inertial Guidance: Introduction, inertial sensors, coordinate systems and its transformation, Schuler tuning and gimbaled platform systems. Guidance used for ballistic missiles.

Missile control methods: Aerodynamic and thrust vector control, Polar and Cartesian control

Mathematical modeling: Force and moment equations. Linearization. Transfer function representation of airframe

Missile servo system: Hydraulic, Pneumatic and Electromechanical

Missile instruments: accelerometer, gyroscopes, altimeter, resolvers

Autopilot design based on classical approach: Roll stabilization. Lateral autopilots based on various combinations of rate gyro and accelerometer feedbacks. Three loop autopilot.

Modern control of missile: State space representation of missile dynamics. Controllability and Observability. State feedback control, Pole placement techniques, Design of observers. Missile autopilot designs based on state space methods.

Text/References:

14. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, New Delhi, 2001.
15. P Zarchan, Tactical and Strategic Missile Guidance, Vol 199 of Progress in Astronautics and Aeronautics, AIAA, Reston, VA, 2002.
16. P. Garnell, Guided Weapon Control Systems, 2nd Ed, Pergamon Press, London, 1980.
17. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, New York, 2004.
18. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.
19. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.

AE 611 UAV Guidance & Control

UAV Guidance: Overview of UAV guidance techniques, General guidance laws for UAVs , Kinematic models for guidance, Path planning, Way-point guidance, Path following for straight line and orbits, Guidance of swam of UAVs, obstacle avoidance guidance. Vision Based Navigation and Target Tracking for Unmanned Aerial Vehicles

Inertial guidance: Introduction, inertial sensors, coordinate systems and its transformation, Schuler tuning and related issues. INS systems , GPS-INS Integration, Data fusion.

Servo systems : Electromechanical

UAV Mathematical Modeling: Equations of Motion for an Unmanned Aerial Vehicle, Coordinate Systems, Small Perturbation Theory, linearization and transfer function representation. Stability Analysis for Unmanned Aerial Vehicles.

UAV Control: Classical Controller Design for Unmanned Aerial Vehicles**,** Lateral-directional and longitudinal autopilot design using success loop closure. Modern control of UAVs: State space representation of UAV dynamics. Controllability and Observability. Design of UAV autopilots based on State feedback, Design of observers. Advanced modern techniques for UAV autopilot design.

Text/References:

1. Amitava Bose, Somnath Puri, Paritosh Banerjee**,** Modern Inertial Sensors and Systems, Prentice-Hall of India, 2008.
2. Ian Moir, Allan Seabridge, Malcolm Jukes, Military Avionics Systems, Wiley, 2006.
3. Jay Gundlach, Designing Unmanned Aircraft Systems: A comprehensive Approach, AIAA Education Series, AIAA, 2012.
4. Rafael Yanushevsky, Guidance of Unmanned Aerial Vehicles, CRC Press, 2011.
5. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.
6. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.
7. Randal W. Beard and Timothy W. McLain, Small Unmanned Aircraft Theory & Practice, Princeton University Press, 2012.

AE 612 Experimental Aerodynamics

Need and Objectives of Experimental study, Fundamentals of Aerodynamics, Governing equations.

Wind Tunnels: Classification of wind tunnels, Subsonic wind tunnel, Transonic wind tunnel, Supersonic wind tunnel, Hypersonic wind tunnel, Special purpose wind tunnels: Icing tunnel, plasma tunnel, shock tubes, atmospheric tunnel, automobile wind tunnel etc., Wind Tunnel Instrumentation & Calibration, Wind tunnel balances.

Pressure Measurements: Manometers, Pressure Probes, Pressure transducers, Pressure sensitive paints.

Velocity measurements: Pressure-based velocity measurements, Hot-wire anemometers (CTA & CCA), Laser Doppler anemometer (LDA), Particle Image Velocimetry (PIV).

Temperature Measurements: Thermocouples, RTD, Temperature sensitive paints, Pyrometers.

Flow Visualization: Surface flow visualization, Tufts, Particle tracer methods: Smoke or Die injection method, Smoke wire, Helium or Hydrogen bubble technique, Optical methods: Shadowgraph, Schlieren photography and Interferometry. Measurement of aerodynamic forces and moments.

Specific experimental environments & measurement techniques, flight testing, data acquisition, Data processing, Uncertainty analysis.

Text/References:

1. Alan Pope & John J. Harper, Low-speed Wind Tunnel Testing, John Wiley & Sons, 1966.
2. Alan Pope & Kennith L. Goin, High-Speed Wind Tunnel Testing, John Wiley & Sons, 1965.
3. Bernhard H. Goethert, Transonic Wind Tunnel Testing, Pergamon Press, 1961.
4. E. Rathakrishnan, Instrumentation, Measurements and Experiments in Fluids, CRC Press, Taylor & Francis Group, 2009.
5. Doeblin.E.O. Measurement systems Applications and design. 5th ed. McGrawHill, 2003

AE 613 Computational Aerodynamics

Governing equations, model equations and classification of PDEs. Euler equations, Navier Stokes equations, Burger's equation.

Introduction to finite difference, finite element and finite volume methods.

Basics of grid generation. Structured grid, unstructured grid

Analysis of numerical schemes for accuracy, stability, dispersion and dissipation. RK method, schemes with spectral-like resolution, Riemann solver, TVD, and ENO. Implementation of boundary conditions.

Boundary layer, shock-capturing, turbulence, aeroacoustic and aeroelastic computations.

Text books :

1. C. Hirsch, *Numerical Computation of Internal and External Flows,* Volumes 1 & 2, Butterworth-Heinemann, Oxford, 2007
2. J. F. Thompson, B. K. Soni, N. P. Weatherill, *Handbook of Grid Generation*, CRC press, Taylor & Francis, 1998
3. E. F. Toro, *Riemann Solvers and Numerical Methods for Fluid Dynamics*, 3rd Ed, Springer, 2009
4. S. B. Pope, *Turbulent Flows*, Cambridge University Press, 2000
5. J. Blazek, *Computational Fluid Dynamics: Principles and Applications*, 2nd Ed, Elsevier, 2006

AE 614 Structural Dynamics and Aero-elasticity

Single, Double and Multi-Degree-of-Freedom Systems: Review of SDOF systems, Free/forced and damped/undamped vibrations, Determination of modal parameters (natural frequencies, mode shapes, and damping), Orthogonality of modes, Steady state and transient response using modal analysis.

Continuous systems: Vibration of strings, bars, and beams (Euler and Timoshenko beam theories); Various boundary conditions; Determination of natural frequencies and modes; Modeling of damping, Rayleigh method, Steady state and transient response using modal analysis, Approximate methods for computing natural frequencies and modes.

Aeroelasticity: Static and dynamic aeroelasticity, Discrete models for aeroelastic problems, Steady state aeroelastic phenomenon with specific reference to wing divergence and control system reversal. Flutter analysis and prediction.

Texts/ References:

1. D. H. Hodges & G. Alvin Pierce, Introduction to Structural Dynamics and Aeroelasticity, Cambridge University Press, 2002
2. Raymond L. Bisplinghoff, Holt Ashley & Robert L. Halfman, Aeroelasticity, Courier Dover Publications, 1996

AE 615 Estimation and Tracking for Aerospace Application

Prolog: Historical Review Of Estimation Theory, Application of Estimation Theory in Engineering. Application to Aerospace Problem (Offline and Online Estimation).

• **Review of probability theory and random variables:** Vector and matrices, Probability and random process, Correlation function, Stationary process, Ergodic process, Power spectral density, Uniform distribution, Random distribution, Gauss Markov process, Random noise model.

• **Classical Offline Estimation Theory:** Cramer-Rao lower bound, Minimum variance unbiased estimation, Least squares estimation, Method of Maximum likelihood Estimation (MMLE).

• **Online Estimation Theory:**

a) **Linear dynamical systems with random inputs:** Linear stochastic systems, objectives. Continuous-time linear stochastic systems: state space model and solution of continuous-time state-space representation. Discrete-time linear stochastic systems: state space model and solution of discrete-time state-space representation.

b) **Linear estimation in linear static and dynamic systems:** Linear minimum mean-squared error estimation. Principle of orthogonality. Least squares (LS) recursive estimation. Kalman filter (KF). Derivation. Matrix Riccati equations. Innovations process. Orthogonality issues. Gauss Markov Process

c) **Estimation for kinematic models:** Discretized continuous-time kinematic modes. Direct discrete kinematic models. LS and KF estimation for noiseless kinematic models. Steady state filters ((α, β)) tracker for noisy kinematic models .Process and Measurement Noise

d) **Adaptive Nonlinear Estimation and maneuvering targets:** Derivation of Extended Kalman Filter (EKF) Equations, Filter Divergence, Adaptive estimation of process and measurement noise, and its objectives. Different Kinematic Models, Innovations as a linear measurement of unknown input. Estimation of unknown input. Variable State Dimension approach. Comparison of adaptive estimation for Maneuvering Targets. Use of Extended Kalman Filter (EKF) for simultaneous state and parameter estimation.

e) **Introduction to navigation applications:** Complimentary filtering for navigation. Global Position Systems (GPS)-models, GPS positioning and its accuracy. State space model for navigation. Integrated navigation estimation. Centralized/distributed estimation fusion. Extended Kalman filter for navigation.

• **Application of Estimation Theory To Aerospace Problem:** Parameter Estimation of Spring mass damper system, Aerodynamic Parameter Estimation, Sensor bias estimation, Design of Radar and Seeker online Tracker

Solving the assignment problems using MATLAB tool boxes is mandatory. This proposed course is modification of current elective **AE 615 Estimation with Applications to Tracking and Navigation**

References

1. Dan Simon: Optimal State Estimation, Willey Inter science, First Edition, (2006).
2. Arthur Gelb: Applied Optimal estimation ,The MIT Press, Sixteenth Reprint Edition, (2001).
3. Yaakov Bar-Shalom, X. Rong Li and Thiagalingam Kirubarajan: Estimation with Applications to Tracking and Navigation: Theory Algorithms and Software, John Wiley and Sons Inc. First Edition, (2001).
4. Frank L Lewis, Lihua Xie and Dan Popa: Optimal and Robust Estimation with an introduction to Stochastic Control Theory, CRC Press, Second Edition, (2008).

AE 616 Nonlinear and Robust Control

Introduction to Nonlinear Systems, Stability analysis, Feedback linearization, Input-State and Input-Output Linearization, Robust Feedback Linearization. Sliding Mode Control and Sliding Mode Observers. Uncertainties, variation and unmodelled lags. Robust control based on Uncertainty and Disturbance Estimation. Time Delay Control, Inertial Delay Control. Disturbance Observer. State and Disturbance Observers. Applications in missile and aircraft autopilot design.

Texts/ References:

1. J.J.E. Slotine and W. Li, Applied Nonlinear Control, Prentice-Hall, NJ, 1991.
2. P. Garnell: Guided Weapon Control Systems, Pergamon Press, London, 1980.
3. A. Sabanovic, L. Fridman, and S. Spurgeon, Variable Structure Systems: From Principles to Implementation, IEE Control Series No. 66, 2004.

AE 617 Avionics

Maps and geodesy; co-ordinate systems and transformations; great circle and rhumb line navigation; dead reckoning; INS-gyroscopes and accelerometers, platform stability and strapped down INS; horizontal and vertical mechanizations in INS; baro-altimeter, air speed indicator, compass and gyro compass; radio navigation - beacons, VOR, DME, LORAN and other nav-aids; primary and secondary surveillance radars; Doppler navigation; GPS principles - space and control segments architecture; DOP and computation of position and velocity; GPS in air, surface and space navigation; considerations in air traffic control. Aids to approach and landing. Head-Up displays: Helmet mounted displays; Headdown displays. Data fusion. Displays Technology. Control and data entry. Radar and communication FMS. Avionics system integration. Data bus. Introduction to safety systems.

Texts/References:

1. Albert Helfrick, Principles of Avionics, Avionics Communications, 2009
2. Myron Kayton & Walter R. Fried, Avionics Navigation Systems, John Wiley & Sons, 1997.

AE 618 Signals and Systems

Representation of Signal: Continuous and discrete time signals - definition and mathematical representation of basic signals- step, impulse, ramp and exponential signals. Classification of Signals Periodic, aperiodic, even, odd, energy and power signals. Deterministic and random signals, complex exponential and sinusoidal signals, periodicity. Transformations: time scaling, time shifting. Determination of Fourier series representation of continuous time and discrete time periodic signals. Explanation of properties of continuous time and discrete time Fourier series.

• **Analysis of continuous time signals and systems**: Continuous time Fourier Transform and Laplace Transform: analysis with examples, basic properties-Linearity, Time Sift, frequency shift, time scaling, Parsevals relation and convolution in time and frequency domains. Basic properties of continuous time systems with examples: linearity, causality, time invariance, stability. Magnitude and Phase representation of frequency response of LTI systems. Analysis and characterization of LTI systems using Laplace transform. Computation of impulse response and transfer function using Laplace transform.

• **Sampling theorem and Z-transform**: Representation of continuous time signals by its samples. Sampling theorem. Reconstruction of a Signal from its samples. Aliasing. Ztransform: definition of Z-transform, region of convergence, examples, Poles and Zeros. Properties of Z-transform with examples.

• **Inverse Z-transform**: Inverse Z-transform using Contour integration. Residue Theorem. Power Series expansion and Partial fraction expansion. Relationship between z-transform and Fourier transform. Computation of Impulse, response and Transfer function using Z Transform.

• **DFT and discrete time systems**: Definition, properties and examples, Discrete time LTI systems. Properties: - linearity, causality, time invariance, stability, static and dynamic. Characterization using difference equation. Block diagram representation,examples, Properties of convolution, interconnection of LTI Systems Causality and stability of LTI Systems. Realtime implementation issues and fast Fourier transform (FFT).

• **Design of Frequency Domain Filters**. Design of low-pass, high-pass, notch filters. Solving the assignment problems using MATLAB tool boxes is mandatory.

References

1. Vinay Ingle and John G Proakis: *Digital Signal Processing Using MATLAB* , Congage Learning, Third Edition, (2012).
2. E Oran Brigham: *The Fast Fourier Transform and Its Applications*, Prentice Hall, First Edition, (1988).
3. A V Oppenheim, R W Schafer and John R Buck: *Discrete Time signal Processing*, Prentice Hall, Second Edition, (1999).
4. A V Oppenheim, A S Willsky and S Hamid: *Signals and Systems*, Prentice Hall, Second Edition, (1996).

AE 619 Robotic Path Planning and Control

Unit I: Time Response: Transient response and steady state error analysis of first and second order systems. Stability analysis Frequency response, Root locus analysis, Nyquist Criteria, design of compensators - state space method: Introduction to State space representation of dynamical systems. Solution of state equation. Controllability and observability, State feedback control, Pole placement techniques and design of observers.

Unit II: Trajectory Planning: Definitions and Planning tasks, Joint Space techniques, Cartesian Space techniques, Joint Solace versus Cartesian Space Trajectory Planning –Obstacle Avoidance, Path Planning, Control of Manipulators: Open and Close Loop Control, The Manipulator Control problem, Linear control Schemes, Characteristics of second order linear systems.

Unit III: Linear Second Order-Order SISO Model of a Manipulator Joint, Joint Actuators, Partitioned PD Control Scheme, PID Control Scheme, Computed Torque Control, Force Control of Robotic Manipulators, Description of force control tasks, Force control strategies, Hybrid Position/ Force Control, Impedance Force/ Torque Control.

Textbooks:

1. K. Ogata, Modern Control Engineering, 5th Edition, Prentice Hall, 2010.
2. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.
3. J.J.E. Slotine and W. Li, Applied Nonlinear Control, Prentice-Hall, NJ, 1991.
4. M. W. Sponge and M. Vidyasagar, Robot Dynamics and Control, John Wiley & Sons, New York, USA, 2004.

AE 620 Optimal Control with Aerospace Applications

- **Introduction and review of basic concepts**: Introduction, motivation and overview, matrix algebra, review of numerical methods.

- **Static optimization:** Unconstrained optimization, constrained optimization - Lagrange multiplier, equality constraints, inequality constraints, neighboring optimum solutions. Numerical solutions. Linear programming problems. Nonlinear programming, Kuhn Tucker condition, Direct optimization by gradient methods. Solutions of static optimization problems for both constrained and unconstrained case.

• **Optimal control of continuous time system by indirect method:** Optimal control through calculus of variation, EulerLagrange necessary condition, Legendre necessary condi- tion, Jacobi necessary condition, Bolza problem, Mayer problem, Lagrange problem, Some sufficiency conditions to the simplest problem, Transversability conditions, Complete opti- mal control formulation using calculus of variation. Fixed terminal time and free terminal time problem, Continuous-time linear quadratic regulator (LQR). Steady-state closed-loop control and suboptimal feedback, Numerical solution of two-point boundary value problem.

• **Optimal control of continuous time system by direct method:** Simple shooting method, Multiple shooting method, Collocation method, Pseudo spectral methods.

• **Comparison of direct and indirect method of solution:** Solution of Brachistochrone problem, Flight Vehicle trajectory optimization using both methods with in flight path constraints and terminal constraints. Advantages and disadvantages of indirect and direct methods.

Solving the assignment problems using MATLAB tool boxes is mandatory.

References:

1. R Venkatraman: Applied Optimization with MATLAB Programming , John Willey and Sons, Second Edition, (2004).
2. S S Rao: Engineering Optimization, Theory and Practice ,John Willey and Sons, Fourth Edition, (2009).
3. Kalyanmoy Deb: Optimization for Engineering Design (Algorithms and Examples), Eastern Willey Edition, Second Edition, (2012).
4. John T Betts: Practical Methods for Optimal Control and Estimation Using Nonlinear Programming , SIAM Publishers, Second Edition, (2010).
5. Frank L Lewis, D L Vrabie and V L Syrmos: Optimal Control, John Willey and Sons, Third Edition, (2012).

AE 621 Advanced Missile Guidance

Inertial Navigation Systems: Kinematics, Angular Velocity and torque equations of gimballed system, errors in INS; Strap Down Inertial Navigation System: Inertial Alignment System, flow diagram and direction cosine computation algorithm of SDINS.

Global Positioning System: Introduction, modes of operations, signals and codes, position fixing, Differential GPS and GPS coordinate transformation. Kalman filtering and integration of GPS and INS.

Missile Guidance loop design studies, Guidance loop model, Normalised homing time and normalised miss distance, variants of PN Laws, Optimal guidance Law, performance comparison of different guidance Laws.

Guided missile design: Top down approach; Guidance & control systems specifications, specifications on aerodynamics, Roll dynamics & rolling moment gradient limit, Autopilot & it's hardware. Requirements, Seeker specifications- Range, Antenna & radome slope error specs
RF & IR Seeker based Guidance, Seeker angle tracking and stabilization systems – Isolation & Decoupling; Nominal scheme & Decoupling loop scheme based approach for guidance – Generic performance comparison; LOS reconstruction approach for faster cost effective homing guidance, performance comparisons of different schemes through 3-DOF simulations.
Radome error modelling, Guidance & control system with radome error-static effects and dynamic effects, Deleterious effects of radome error on guidance, Radome error characterization and compensation

Seeker estimator: Inside and outside seeker mechanization, performance comparison, eclipsing effects & performance-Multiple PRF seeker

Text/References

1. P. Garnell, Guided weapon control systems, 2nd ed, pergamon press, London, 1980
2. G.M. Siouris, Missile Guidance and control systems, springer verlag, New Yor, 2004
3. Merill I. Skolnik, Introduction to Radar system, Tata Mc Hill, New Delhi, 2001

AE 622 Ducted Rocket & Combustion

Ramjet and integral rocket ramjet: Thrust and thrust coefficients, effective jet velocity, Combustion efficiency, Classification and comparison of IRR propulsion system. Two-phase nozzle flows, Scramjet, Solid fuel ramjets, Advances in Propulsion Technology.

Experimental techniques for rocket testing: General layout of solid, liquid, and IRR Thrust stand, auxiliaries, safety measures. Thrust, pressure, flow and temperature measurements. Evaluation of tests.

Combustion: Pre-mixed flames - flame speed, inflammability limits, one dimensional flame propagation, Diffusion flames, Detonation and deflagration.

Texts/ References:

1. M.J. Zucrow and J.D. Hoffman, Gas dynamics, Vol. I, John Wiley and sons, New York, 1976
2. M.J. Zucrow, Aircraft and Missile Propulsion, Vol II, John Wiley and Sons, New York, 1958
3. K. Kuo, Principles of Combustion, 2nd Ed, John Wiley & Sons, 2005
4. I. Glassman, Combustion, Ist Ed, Academic Press, San Diego, California 1997

AFW 601 Ballistics of Bombs & Projectiles

Basics of Ballistics of any projectile, Difference between precision, accuracy and CEP. Internal Ballistics (Guns): Burning of propellants, Vielle's mode and rate of burnings, form function, Resalls' Energy Equation. Internal ballistic solutions, effect of vibrations in loading conditions, Similarity relations. External Ballistics (Guns): Aerodynamic force system. Normal equations. Numerical methods of trajectory computation, Meteorological corrections. Angular motion of the Centre of mass. Drift and deflection, Dispersion of fire. External Ballistics of Rockets: Launch dynamics, plane trajectory, boost plane trajectory models, rocket accuracy (dispersion and stability), rocket-assisted projectiles. Bomb Ballistics: Aerodynamic forces and moments acting on a bomb, Drag co-efficient, Terminal velocity and Ballistic index, Trajectory of bombs, Simulated stores (similitude) and their trajectories, Bomb stability derivatives and analysis (in roll, pitch and yaw), wind tunnel testing, Bomb trajectory calculations with point mass and Six Degrees of Freedom Equations. Calculation of Moment of Inertia and Centre of Gravity of bombs.

Text/References:

1. Text Book of Ballistic & Gunnery, Vol I & II, HMSO Publication,1987,.
2. Ballistics Theory and Design of Guns & Ammunition, DE Carlucci & SS Jacobson, CRC Press. 2007,
3. Military Ballistics: A Basic Manual (Brassey's New Battlefield Weapons Systems and Technology Series into 21st Century), CL Farrar, DW Leeming, GM Moss, Brassey's (UK) Ltd. 1999,
4. Modern Exterior Ballistics, ,Robert L McCoy, Schiffer Publishing. 2001

AFW 602 Design of Air Armament - I

Aerodynamics Decelerators: definitions, types, applications of parachute for escape, recovery and armaments systems. Supersonic inflatable decelerators.

Parachute characteristics: opening characteristics, aerodynamic drag &wake effect, shock load, snatch force, inflation process, reefing, clustering, pressure distribution, deployment methods, critical speeds, parachute stability, stress analysis, trajectory and motion of deployed parachutes, impact attenuators. Parachute malfunctions.
Parachute materials, porosity of fabric. Parachute & reefing system design, Case study on design of parachute recovery and landing system. Testing of Parachutes

Design of aircraft bombs & tail units: Classification, design data, factors affecting bomb design, spatial functioning considerations, bomb design for stability and accuracy requirements. Design and use of cluster bomb.

Design of HE Bomb: Bombs case design, analysis of stresses in thin and thick cylinders, various failure theories, stages of manufacturing of forged bomb case

Design of penetration bomb: description of concrete, crushing strength, setting & hardening. Behavior of concrete on impact of projectile, factors affecting penetration, effect of reinforcement, mathematical calculation of residual velocity, time of penetration and resistive pressure**.** Analysis of stresses in bomb case during normal impact on concrete. Calculation of penetration & depth resistive pressure in rock & soil.

Fuses : Classification, general design considerations, principles of fuse initiation, design, working and safety features of mechanical fuses, safety & arming devices. Introduction to electrical, electronic fuses, proximity and long delay fuses. Latest trends in fuse development

Guided Bombs: Classification and types, Design Criteria, Working principle, Type of Lasing equipment (LDP, PLDs, UAV assisted). Range Enhancement techniques.

Chaffs, flares, EAX and power cartridges: Basic principles, design aspect and lifting methodology.

Text/References:

1. Text Book of Air Armament, Royal Air Force publication.
2. Irwin, Recovery System design Guide, 2006.
3. Air Force Wing Précis on Stores Separation.
4. Knacke TW, Parachute Recovery System Design Manual, 2008.
5. Performance & Design criteria for Deployable Aerodynamic Decelerators (*N*TIS).
6. Air Force Wing Précis on Bomb and Fuse Design.

AFW 603 Airborne Weapon System Effectiveness

Basic tools and methods used in Weaponeering: Weaponeering process, elementary statistical methods, weapon trajectory, delivery accuracy of guided & unguided armaments, target vulnerability assessment, introductory and advanced methods.

Weaponeering process of air launched weapons against ground targets: single weapon directed against point & area target, Stick deliveries, projectiles, cluster munitions, Weaponeering for specific target (bridges, building, tunnels etc), simple collateral damage modeling, and direct & indirect fire system.

Introduction to Fire Control System: definitions, classification, applications of modern FCS.

Text/References:

1. Feller W, An Introduction to Probability Theory and Its Applications, Vol. I & II, 3rd Edition, John Wiley, 2000.
2. Driels M, Weaponeering, AIAA Education series, 2004.

AFW 604 Warhead Design & Mechanics

Introduction to warhead: Configuration and classification. Formation of kill mechanisms and target interaction. Omni-directional, directional and directed energy warheads. Explosives used in warheads.

Blast warheads: Explosion dynamics. Specifications of blast wave. Propagation of blast wave in air. Evaluation and parametric study of blast. Empirical relations and scaling laws. Peak over pressure, Impulse and Damage Number concept. Damaging aspect and target damage criteria of blast warhead. Thermo Baric weapons.

Fragmentation Warheads: Principles, classifications and design considerations. Natural, preformed and controlled fragmentation. Fragment initial velocity and direction of projection calculation. Fragment mass distribution and computation. Aerodynamic effects on fragment motion. Warhead shape design and geometric modeling of fragmentation warhead. Focused mass fragmentation. Kinetic energy rod warheads. Fragment and target interaction mechanics.

Shaped charge warheads: Configuration and classifications. Hollow charge, Flat cone charge and projectile charge warheads. Liner collapse and jet formation mechanism. Jet and slug characterization: Birkhoff theory, PER theory. Jet and slug velocity, mass distribution. Jet radius. Jet break up. Target interaction and jet penetration dynamics. Hydrodynamic theory and rod penetration model. Stretching jet penetration theory. Parameters affecting performance of shaped charge warheads. Wave shapers. Mechanisms to defeat shaped charges.

Introduction to Warhead Simulation techniques.

Text/References:

1. Joseph Carleone, Tactical Missile Warheads, Vol. 155, Progresses in Astronautics and Aeronautics, 1993.
2. Richard M Lloyd, Conventional Warhead Systems Physics and Engineering Design, Vol. 179, Progresses in Astronautics and Aeronautics, 1998.
3. W. P. Walters and J. A. Zukas, Fundamental of Shaped Charges, Wiley- Inter Science Publication,1989.
4. Richard M Lloyd, Physics of Direct Hit and Near Miss Warhead Technology, Vol. 194, Progresses in Astronautics and Aeronautics, 2001.
5. DIAT Air Wing Précis I – 14.

AFW 605 Air Armament Control & Guidance

Basic design features, Design Criteria, Classification and types of Air Launched Missiles, Specific design requirements.

Missile Controls: Missile control methods: Aerodynamic and thrust vector control, Polar and Cartesian control.

Mathematical modeling: Force and moment equations. Linearization, Transfer function representation of airframe.

Missile servo system: Hydraulic, Pneumatic and Electromechanical.

Missile instruments: Accelerometer, gyroscopes, altimeter, resolvers.

Autopilots Design: Autopilot design based on classical approach: Roll and roll rate stabilization. Lateral autopilots based on various combinations of rate gyro and accelerometer feedbacks. Three loop autopilot.

Introduction to sensors & signal processing

Radar Systems: Fundamentals of Radar, Introduction to Pulse, CW, FM-CW & MTI Radar, Tracking Techniques.

Guidance System: Classification of guidance system, phases of guidance, command guidance, MMW seeker head, image infra-red, scene correlation area navigation system and laser based system. Introduction to INS and SDINS.

GPS: Introduction, description of satellite coordinates and calculation of user coordinates. Concept of GPS INS integration.

Missile Kinematics: Trajectory computation, time of flight, Lateral acceleration demand and turning rate for various courses.

Text/References:

1. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, 2001.
2. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, 2004.
3. G.C. Goodwin, S.F. Graebe, and M.E. Salgado, Control System Design, Prentice-Hall, New Delhi, 2002.

AFW 606 Design of Air Armament – II

Aircraft Guns: Design Criteria, Specific design requirements, Energy requirements in aircraft guns (automatic, blowback, recoil and gas operation), Gatling guns, kinematics diagram. Design of buffers & recuperators, Gun barrels designing and rifling, muzzle breaks & boosters, Current trends in aircraft automatic gun design.

Aircraft Ammunition: Classification and types of ammunition, Design Criteria, Specific design requirements, Gun ammunition propellant and their characteristics, optimization of grain size for a given weapon. Cartridge case design, Ignition system design, Stability of projectile, driving band design, stresses in shells. Terminal considerations and design of ac gun ammunition fuses. Modern trends in ammunition design.

Aircraft Rockets: Design considerations, proof and testing of aircraft rockets.

Text/References:

1. Jacobson SS, Ballistics, CRC Press, 2008.
2. Engineering Design Handbook: Automatic Weapons, AMCP No. 706 – 260, US Army Material Command, Washington, 1990.
3. Brassey's Essential Guide to Military Small Arms: Design Principles and Operating Methods, D Allsop, L Popelinsky et al, 1997.
4. The Machine Gun: Design Analysis of Automatic Firing Mechanisms and Related Components, GM Chinn, Bureau of Ordnance, Department of Navy, US, 1955.
5. Aerodynamics, Propulsion and Structure, E. A. Bonney, M. J. Zucrow, and C. W. Besserer, D.Van Nostrand, New York,1956.
6. Rapid Fire, 2005, William AG, The Crowood Press, UK.

AFW 607 Testing and Certification of Air Armament Stores

Ground Testing: Gun Ammunition, Rockets, Bombs, Fuses, Parachutes, Missiles. Procedure and Instrumentation setup for Testing & Proof of Air Armament stores, Environmental Testing of Air Armament stores, Airworthiness Certification & Failure Investigation Procedure of Air Armament.

Weapon Accuracy Analysis: Concept of probability, probability distribution, systematic and random errors, error in fire dispersion, probability of kill SSKP, CKP, CEP, (SE, PE, MAE,CPE, CD, EPE,SPE).

Carriage & Release: Design criteria for location of weapon station, Effects of external Carriage and Advanced Carriage concepts, calculation of lug & sway brace reactions for single & twin suspension configuration, Bomb carriers. MIL STD 8591, 7743, 1289.

Mathematical Concept of Stores Separation & Towed body: Similarity concept, stores trajectory simulation, modeling of stores separation.

DDPMAS -2002: Definition, Process of development, Development Phase, Production Phase, Indigenization, Flight Testing by user services.

Procurement Policy: Principals of public buying, preparation and approval of ASQRs, Capital & Revenue procurement of stores.

Composite Materials and polymers for AA applications

Materials: Materials for Bomb/ Rocket and Missile Structures. Introduction to Nano materials for military application.

Text/References:

1. DIAT Air Force Wing Précis and MIL STD 8591, 7743, 1289.
2. Joint services guide on Environmental testing of armament stores and missile JSG-0102-1984 and JSS_0256-01.
3. DDPMAS -2002 and Defence Procurement manual -2008.

AFW 608 Fire Control Systems

Introduction to fire control system: Definitions, classification, application of modern FCS, brief description of aircraft and helicopter FCS.

Theoretical aspects of the FCS problems and its solution

Functional elements of FCS : Acquisition and tracking system, fire control computing system, weapon pointing system, command control & communicating element, data transmitting element, integration of functional element into FCS, compatibility problem.

Design Philosophy: Development of mathematical model & simulation, Model verification & validation, filtering and prediction, accuracy consideration and analysis, hit & kill probability theory, error analysis in FCS, fire control testing.

Designing for reliability, maintainability, ease of operation and safety

Text/References:

1. Department Of Defense Handbook, Fire Control Systems—General, Mil-Hdbk-799(Ar), 1996.
2. BS Dhillon, Design Reliability: Fundamental Applications, CRC Press, 2004.
3. Air Force Wing Précis.