Program Structure and Syllabus of Honors in Aerospace Technology

ELECTRONICS & COMMUNICATION ENGINEERING (ECE)

AR25_Regulations

ANURAG UNIVERSITY

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Honors in Aerospace Technology

Curriculum Structure

S.No	Course Code	Course Name	Credit Scheme			
			Lecture	Tutorial	Practical	Total Credits
1	EH25014	Space Environment and Its Effects on Orbital Spacecrafts (MOOCs)	3	-	-	3
2	EH25015	Launch Vehicle Systems and Technologies (MOOCs)	3	-	2	4
3	EH25016	Space Flight Mechanics (MOOCs)	3	-	2	4
4	EH25017	Drone Systems and Control (MOOCs)	3	-	2	4
5	EH25P01	Project	-	-	6	3
	Total		**12**	**00**	**12**	**18**

Note:

If MOOCs courses are not available for any reason on SWAYAM/NPTEL or any notified certification examinations, student shall register for a university-conducted examination for 100 marks through self-paced learning.

ENVIRONMENT AND ITS EFFECTS ON ORBITAL SPACECRAFTS

Honors Degree in Aerospace Technology					Department of Electronics & Communication Engineering			
Code	Category	Hours / Week			Credits	Marks		
EH25014	Core	L	T	P	C	CIE	SEE	Total
		3	0	0	3	-	100	100

Pre-requisites: Knowledge of the elementary theories related to Physics and Mathematics and Chemistry

COURSE OUTLINE:

The hazardous interactions between the space environment and the orbiting spacecraft may lead to the degradation of spacecraft and its subsystem performance and may lead to the loss of the spacecraft itself. This course aims to provide the students with the introduction to the understanding of different aspects of the space environment, including vacuum environment, neutral particulate environment, space debris, plasma and radiation environment and how this impact on spacecraft design, human and robotic spaceflight, terrestrial infrastructure systems and will enable students to explore a particular topic at a deeper level. Emphasis is laid on problem solving techniques and design guidelines that will provide the student with an understanding of how space environment effects may be minimized through proactive spacecraft design.

COURSE PLAN:

Week 1: Introduction to Space Environment and Spacecraft Interactions

Space environment, its types and weather definition, anatomy of Sun, Solar activities as space weather driver, Solar wind, solar flare, coronal mass ejection, solar energetic particles event, Co-rotating Interaction regions, interplanetary magnetic field (IMF), Coupling of solar wind to earth's magnetosphere and ionosphere, geomagnetic storm and substorm, geomagnetic indices, Earth's radiation belt, and ring current, south Atlantic anomaly.

Week 2: Satellite system and its orbit:

Different types of earth's orbit for useful satellite applications like LEO, MEO and GEO/GSO, HEO, PEO.
Space environment at different earth's orbits and the applications of the artificial satellites at different orbital altitudes. Satellite space segments 1; Mechanical main frames 1; structures, thermal control system. Satellite space segments 1; Mechanical main frames 1; structures, thermal control system. Electrical main frames 2; Altitude and orbit control system, station keeping, TT and C, payloads.

Week 3: Satellite system:

Earth segments 1; Receive-Only Home TV Systems, Transmit-Receive Earth Stations.
Earth segments 2; Important subsystems of a typical satellite earth station and Important considerations for satellite operations. The vacuum spacecraft environment: Characteristics of vacuum environment, heat transfer mechanisms in vacuum and its implication of spacecraft thermal design and challenges. UV radiation exposure of satellites and its effects, out-gassing effects of spacecraft materials, definition of TML, CVCM, WVR and its' significance. Ground Simulation of vacuum environment, thermo-vacuum chamber, thermo-vacuum test philosophy, Characterization of TML, CVCM and WVR.

Week 4:

Material selection, design guidelines and mitigation techniques for vacuum environment. The neutral environment 1. Neutral gas flow around a spacecraft, earth's atmosphere, pressure, density and temperature variation with altitude. Planetary atmospheres, aerodynamic force; contamination, erosion by atomic oxygen, spacecraft glow.
Particle impacts on spacecraft, scattering of EM radiation from particles.
The physics of macroscopic particles, cometary, meteoroids, asteroidal meteors.

Week 5:

Spacecraft induced neutral Environments, Spacecraft outgassing; chemical thrusters.

Space debris, its types, space debris management, monitoring, detection and capturing methods. Simulation, modeling and mitigation techniques for effects neutral environment. Plasma Environment 1: Basic charged Particle Motion in Constant Electric and Magnetic Fields, gyro-radius, cyclotron frequency. ExB drift, Debye shielding, plasma frequency, magnetic mirroring.

Week 6: Plasma Environment 2:
Geomagnetic storm/substorm and the external and disturbance fields, Plasma environment in low earth orbit and polar orbits and interaction with spacecrafts, The geosynchronous orbit plasma environment; spacecraft-plasma interactions, The physics of spacecraft charging, spacecraft potential, Spacecraft surface charging, absolute charging, differential charging.

Week 7: Plasma Environment 3
General probe theory: the thin-sheath limit, the thick-sheath limit, spacecraft potentials, Langmuir probe. Spacecraft as a Langmuir Probe, Current Collection in spherical, cylindrical and plane geometry. Energy distribution of plasma species, Single Maxwellian and double Maxwellian distribution, Spacecraft charging in a Maxwellian plasma. Current from the ambient plasma, photoelectric currents, backscattered and secondary electrons. Current balance equation, computation of spacecraft built-up potential.

Week 8: Plasma Environment 3
Effect of magnetic fields on current collection, artificial current and charge sources. Space Tethers, Plasma Contactors, and Sheath Ionization. Electrostatic Discharges on Spacecraft: Location of discharges on spacecraft, differential charging, electromagnetic Interference. Bulk or internal spacecraft charging: high-energy electron and ion fluxes, penetration of high-energy charges into materials, properties of dielectrics, avalanche ionization in a high electric field. Satellite anomalies due to spacecraft charging, modelling, simulation and testing.

Week 9: Plasma Environment 4
Design guide lines and mitigation techniques against spacecraft charging Radiation environment 1 Electromagnetic radiation, electromagnetic radiation at radio frequencies, visible and infrared, UV, EUV, and X-rays; Energetic particle radiation; trapped radiation, cosmic rays, Solar proton events. Radiation belts, radiation belt electron population, nominal electron belt structure and dynamics, solar wind drivers of radiation belt dynamics. Radiation interactions with matter, single-particle interactions, photon interactions, charged-particle interactions, neutron interactions.

Week 10: Radiation environment 2
Space radiation risks to astronauts, case studies of ISS. Effects on spacecrafts, Single event effects, total ionization dose, displacement damage. Radiation charging of dielectric materials, physics of radiation-Induced charging, radiation-induced bulk discharges. Modeling, Simulation, and Testing

Week 11: Radiation environment 3
Coupling, victim, spacecraft radiation hardening

Test and evaluation, design guidelines, material selection, wiring and cable shields and their bonding. Spacecraft radiation hardening, Radiation Hardness Assurance. Design guidelines and mitigation techniques for the effects of radiation environment. Risk assessment, reliability 1. Failures Caused by the Space Environment, a review of different space missions anomalies. Risk assessment and management, general guidelines for risk assessment

Week 12: Risk assessment, reliability 2
Reliability and Quality Assurance, Parts reliability. Satellite system availability Mission planning, Spacecraft operations and safety.

Space mission drivers, different considerations of mission planning. Spacecraft operations: fault management systems, Autonomy in spacecraft operations, different approaches

Launch Vehicle Systems and Technologies

Honors Degree in Aerospace Technology					Department of Electronics & Communication Engineering			
Code	Category	Hours / Week			Credits	Marks		
EH25015	Core	L	T	P	C	CIE	SEE	Total
		3	0	2	4	-	100	100

Prerequisites: Engineering Physics, Engineering Mathematics

Course Objectives: Familiarize students with

1. Concepts of launch vehicle design and missiles
2. Launch Vehicle Dynamics
3. Fundamentals of GNC loop, design problem and algorithms
4. Mechanism of Descent and landing

Unit–I:Launch Vehicles and Missiles and their subsystems

Launch Vehicles and Missiles and their subsystems, Fundamentals and Types of Propulsion system: Solid / Liquid / Cryogenic / Semi-Cryogenic /Mono- propellent, Bi-propellent and Electric propulsion systems (including green propulsion) Fundamentals of Structures and Mechanisms: Structural Dynamics/Vibration modes for Dynamics modeling

Unit –II: Launch Vehicle Dynamics

Gravity model, Point mass dynamics, Aerodynamics: Multi-strap-on Vehicles, its aerosurfaces, Fundamentals of Trajectories (Mission Design): Equations of Motion: short period / long period Model development, Slosh Dynamics analysis, Basic principles of inertial measurement units: Gyros, Fiber optic/ Laser Gyros and others, accelerometers, Actuators: Electrohydraulic, Electromechanical, Reaction Control Systems

Unit –III: Fundamentals of GNC loop, design problem and algorithms

Basics of Guidance: Open Loop / Closed Loop: Implicit / Explicit Guidance schemes, Basics of Navigation: Nav algorithm, compensation schemes, multiple sensor fusion, Basics of Control (Autopilot): Linear / nonlinear design Techniques

Unit –IV: Validation Testbeds/ Simulation setups

On-board computer in the loop simulations (OILS), Hardware in the loop Simulations (HLS), Actuators in Loop Simulations (ALS), Flight Software in Loop Simulations (SILS), reliability analysis, Satellite interface and satellite deployment with separation dynamics

Unit- V: Descent and landing

Descent and landing of jettisoned stages, communication with ground stations, ground tracking in collaboration with foreign space center

Text Books

1. Edberg, D., and Costa, W., Design of Rockets and Space Launch Vehicles, AIAA Education Series, 2020
2. Kadam, N. V., Practical Design of Flight Control Systems for Launch Vehicles and Missiles, Allied Publishers, 2009

Reference Books

1. Wiesel, W. E., Spacecraft Dynamics, 2nd ed, McGraw-Hill 1997
2. Noton, M., Spacecraft Navigation and Guidance, Springer 1998

Course Outcomes: Students will be able to:

1. Discuss concepts of launch vehicle design and missiles
2. Explain Launch Vehicle Dynamics
3. Apply Fundamentals of GNC loop, design problem and algorithms
4. Describe Mechanism of Descent and landing

Practical Assessment:

Based on the course content, the Faculty Mentor will assign problem statements for students to simulate using Open Rocket and Autodesk Fusion tools. Marks are awarded according to the performance of the submitted work.

Space Flight Mechanics

Honors Degree in Aerospace Technology					Department of Electronics & Communication Engineering			
Code	**Category**	**Hours / Week**			**Credits**	**Marks**		
EH25016	Core	L	T	P	C	CIE	SEE	Total
		3	0	2	4	-	100	100

PRE-REQUISITES: Calculus of Multi-variables, Physics, Applied Mechanics

COURSE OUTLINE:

This course is designed to introduce orbital mechanics of satellite. The course will begin with central force motion and then proceed to the two- body and three-body dynamics under mutual gravitational acceleration. It will also introduce the concept of Lagrange Points and their stability. Moreover, the concept of general orbit perturbation will also be discussed. Earth as a non-spherical body and its effect on gravity will be elaborated. Preliminary orbit determination of the satellite will be discussed. Finally, orbit transfer will be elaborated.

COURSE PLAN:

Week 1: Conic Section & Central Force motion

Week 2: Two Body problem (equation of relative motion, integrals of the two-body problem)

Week 3: The Classical Orbital Elements (determination from burnout data and inverse problem of orbit determination)

Week 4: Kepler's Equation and Kepler's Problem (orbit propagation)

Week 5: Three Body/Restricted Three Body Problem (equation of motion)

Week 6: Restricted Three Body Problem (Lagrange points and their stability)

Week 7: General Perturbation Theory (variation of parameters)

Week 8: General Perturbation Theory (variation of parameters)

Week 9: Preliminary Orbit Determination (reference frames and methods of orbit determination)

Week 10: Orbit Transfer (Hohmann and Bielliptic)

Week 11: Orbit Transfer (patched conic section method, interplanetary transfer, flyby)

Week 12: Non-Coplanar Orbit Transfer (Interception and Rendezvous)

Practical Assessment:
Based on the course content, the Faculty Mentor will assign problem statements for students to simulate using Matlab and Satellite Orbit Simulate (SOS). Marks are awarded according to the performance of the submitted work.

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Drone Systems and Control

Honors Degree in Aerospace Technology					Department of Electronics & Communication Engineering			
Code	**Category**	**Hours / Week**			**Credits**	**Marks**		
EH25017	Core	L	T	P	C	CIE	SEE	Total
		3	0	2	4	-	100	100

PRE-REQUISITES: Familiarity with mathematics subjects such as linear algebra, differential equation, etc. Proficiency in Simulink/MATLAB

COURSE OUTLINE:

This course provides a comprehensive introduction to drone technology, encompassing fundamental aerodynamics, simulation, sensor integration, control systems, and autonomous navigation. Beginning with drone types and safety regulations, the course progresses through 6-DoF modeling in Simulink, sensor calibration and Kalman filtering in MATLAB, and classical autopilot design. Advanced topics include path planning algorithms (RRT, A*), obstacle avoidance techniques (potential fields, collision cones, control barrier functions), trajectory tracking, and an introduction to simultaneous localization and mapping (SLAM) and Sim2Real transfer using ROS and AirSim.

Course Plan:

Week 1: Types of drones, Fundamentals of aerodynamics – lift, thrustand drag, safety requirements, regulations, applications. Rigid body transformation/rotation. Dynamic model of multi-rotor.

Week 2: Sensors: IMU (gyro, accelerometer), GPS, altitude sensors,vision-based sensors. Basics of estimation and Kalman filtering. Kalman filtering

Week 3: Extended Kalman filtering. Introduction to control system, Laplace Transforms

Week 4: Control system: Transient response. Control system: Frequency response

Week 5: Control system: Stability. Proportional-integral-derivative controller design

Week 6: Classical auto-pilot design: auto-takeoff and landing. Classical auto-pilot design: auto-stabilization. Classical auto-pilot design: attitude hold and position hold

Week 7: Basics of PX4, MatLab-motors-PX4 interfacing. Design of real-time implementation in flight controller. Experiment: Attitude bench controller tuning

Week 8: Scenario generation, point-to-point navigation. Global path planning: basic algorithms

Week 9: RRT algorithm, A* algorithm

Week 10: Obstacle avoidance, Artificial potential field, Collision cone-based approaches, Control barrier function.

Week 11: Trajectory tracking: PID controller, Trajectory tracking: Model predictive control, Design implementation of sense-and-avoid for multi-rotor aerial vehicle

Week 12: Introduction to mapping, SLAM, Visual SLAM, visual perception, object detection, Sim2Real: ROS, AirSim

Practical Assessment:
Each student will deliver a seminar on a topic related to the course. Marks will be awarded based on the quality of the presentation and supporting materials.

Project

Honors Degree in Aerospace Technology					Department of Electronics & Communication Engineering			
Code	**Category**	**Hours / Week**			**Credits**	**Marks**		
EH25P01	Core	L	T	P	C	CIE	SEE	Total
		0	0	6	3	50	50	100