INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043.

AERONAUTICAL ENGINEERING

COURSE DESCRIPTION FORM

Course Title	**LAUNCH VEHICLE AND MISSILE TECHNOLOGY**			
Course Code	**A82132**			
Regulation	**R13 - JNTUH**			
Course Structure	Lectures	Tutorials	Practical's	Credits
	4	0	-	4
Course Coordinator	Mr. Shiva Prasad U, Assistant Professor, Department of Aeronautical Engineering			
Team of Instructors	Mr. Shiva Prasad U, Assistant Professor, Department of Aeronautical Engineering			

I. COURSE OVERVIEW

The launch vehicle and missile technology is the first course in graduate and undergraduate courses. The advanced course on launch vehicle and missile technology gets specialized in the sub streams of space flight mechanics. The proposed course even though is introductory but effort will be made to expose to the complicacies of the sub streams in space flight mechanics. So that student gets exposure to the various aspects of the subject and can appreciate the complicacies involved which will further imbue curiosity to understand this subject and explore. Even though the main thrust will be on the space flight propulsion but the subject will be enriched with the introduction to rockets which will make the subject matter. Complete in the sense that from the starting phase of launching of a satellite to its orbit maintenance and determination will be covered to give the students a complete glimpse of the subject matter without which it will remain a theoretical exercise which many text books available in this area can provide. A number of problems will be solved to enhance the understanding of the subject matter and besides, many unsolved problems will be provided with answers to further test the student's learning.

II. PREREQUISITE(S)

Level	Credits	Periods	Prerequisite
UG	4	4	Aerospace Propulsion II

III. MARKS DISTRIBUTION

Sessional Marks	University End Exam Marks	Total Marks
Mid Semester Test There shall be two midterm examinations. Each midterm examination consists of essay paper, objective paper and assignment. The essay paper is for 10 marks of 60 minutes duration and shall contain 4 questions. The student has to answer 2 questions, each carrying 5 marks. The objective paper is for 10 marks of 20 minutes duration. It consists of 10 multiple choice and 10 fill-in-the blank questions, the student has to answer all the questions and each carries half mark. First midterm examination shall be conducted for the first two and half units of syllabus and second midterm examination shall be conducted for the remaining portion. **Assignment** Five marks are marked for assignments. There shall be two assignments in every theory course. Assignments are usually issued at the time of commencement of the semester. These are of problem solving in nature with critical thinking. Marks shall be awarded considering the average of two midterm tests in each course.	75	100

IV. EVALUATION SCHEME

S. No	Component	Duration	Marks
1	I Mid examination	80 minutes	20
2	I Assignment	--	05
3	II Mid examination	80 minutes	20
4	II Assignment	--	05
5	External examination	3 hours	75

V. COURSE OBJECTIVES

The course enables the students to:

I. Describe basic difference between rocket and missile, their mission profile, materials used and similarities.
II. Develop fundamentals grain design of solid propellant, cryogenic propellant, Liquid propulsion for various space vehicles.
III. Resolve the aerodynamic forces acting on rockets and missile, decouple the lateral & longitudinal modes of vehicle and re-entry body design considerations.
IV. Understand how rocket equation is derived and observe the behavior of body in absence of gravity.
V. To obtain the knowledge in testing procedures of rocket engines and basic requirements for ground testing.

VI. COURSE OUTCOMES:

After completing this course the student must demonstrate the knowledge and ability to:

1. Distinguish between missile and space launch vehicles and their mission profiles.
2. Develop grain design such that it has an efficient burn rate.
3. Illustrate concepts of cryogenic propellant and its implementation in space vehicles.
4. Design aerodynamically efficient structures for missile and space launch vehicles.
5. Optimize the design of re-entry module, such that heat load, 'g' loads are minimum.
6. Interpret to solve Tsiolskovsky's rocket equation.
7. Implement the tests performed on ground in software's like CFD++/FLUENT/OPEN FOAM.
8. Describe the missile systems and its components.
9. Estimate the performance of missiles and rockets.
10. Classify the types of missiles and their applications
11. Demonstrate various levels of intergration to the separation systems and launch vehicles
12. Recognize the need of hybrid propellants in the launch vehicles and missile bodies

VII. HOW PROGRAM OUTCOMES ARE ASSESSED

Program outcomes		Level	Proficiency assessed by
PO1	**General knowledge:** An ability to apply the knowledge of mathematics, science and Engineering for solving multifaceted issues of Aeronautical Engineering	S	Assignments
PO2	**Problem Analysis:** An ability to communicate effectively and to prepare formal technical plans leading to solutions and detailed reports for Aerospace systems	N	------
PO3	**Design/Development of solutions:** To develop Broad theoretical knowledge in Aeronautical Engineering and learn the methods of applying them to identify, formulate and solve practical problems involving Aerospace industry	H	Assignments
PO4	**Conduct investigations of complex problems**: An ability to apply the techniques of using appropriate technologies to investigate, analyze, design, simulate and/or fabricate/commission complete systems involving generation, transmission and distribution of rocket and missiles.	H	Assignments
PO5	**Modern tool usage:** An ability to model real life problems using different hardware and software platforms, both offline and real-time with the help of various tools along with upgraded versions.	N	------

PO6	**The engineer and society**: An Ability to design and fabricate modules, control systems and relevant processes to meet desired performance needs, within realistic constraints for social needs	S	Seminars
PO7	**Environment and sustainability:** An ability To estimate the feasibility, applicability, optimality and future scope of power networks and apparatus for design of eco-friendly with sustainability	S	Seminars
PO8	**Ethics:** To Possess an appreciation of professional, societal, environmental and ethical issues and proper use of renewable resources	N	------
PO9	**Individual and team work:** An Ability to design schemes involving signal sensing and processing leading to decision making for real time electrical engineering systems and processes at individual and team levels	S	Seminars
PO10	**Communication: A**n Ability to work in a team and comprehend his/her scope of work, deliverables , issues and be able to communicate both in verbal ,written for effective technical presentation	S	Seminars
PO11	**Life-long learning**: An ability to align with and upgrade to higher learning and research activities along with engaging in life-long learning.	N	-----
PO12	**Project management and finance**: To be familiar with project management problems and basic financial principles for a multi-disciplinary work	S	Assignments

N - None S - Supportive H – Highly Related

VIII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED

Program Specific Outcomes		Level	Proficiency Assessed by
PSO 1	**Professional Skills:** An ability to understand the basic concepts in Electronics & Communication Engineering and to apply them to various areas, like Electronics, Communications, Signal processing, VLSI, Embedded systems etc., in the design and implementation of complex systems.	H	Lectures and Assignments
PSO 2	**Problem-solving skills:** An ability to solve complex Electronics and communication Engineering problems, using latest hardware and software tools, along with analytical skills to arrive cost effective and appropriate solutions.	S	Tutorials
PSO 3	**Successful career and Entrepreneurship:** An understanding of social-awareness & environmental-wisdom along with ethical responsibility to have a successful career and to sustain passion and zeal for real-world applications using optimal resources as an Entrepreneur.	S	Seminars and Projects
PSO 4	**Successful career and entrepreneurship:** To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aerospace and allied systems and become technocrats	S	Seminars and Projects

N - None S - Supportive H – Highly Related

IX. SYLLABUS

UNIT- I INTRODUCTION

Space launch vehicles and military missiles- function, types, role, mission, mission profile, thrust profile, propulsion system, payload, staging, control and guidance requirements, performance measures, design, construction, operation- similarities and differences. Materials used for launch vehicles & missiles and their selection criteria.

UNIT-II SOLID & LIQUID PROPELLANT ROCKET MOTOR SYSTEMS

Solid propellant rocket motors, principal features, applications. Solid propellants, types, composition, properties, performance. Propellant grain, desirable properties, grain configuration, preparation, loading. Structural design of grain. Liners, insulators and inhibitors- function, requirements, materials. Rocket motor casing- materials. Nozzles- types.

Liquid propellants- types, composition, properties, performance. Propellant tanks, feed systems-pressurization, turbo-pumps- valves and feed lines, injectors, starting and ignition. Engine cooling, support structure. Control of engine starting and thrust build up.

UNIT-Ill AERODYNAMICS OF ROCKETS AND MISSILES

Classification of missiles. Airframe components of rockets and missiles, Forces acting on a missile while passing through atmosphere, method of describing aerodynamic forces and moments, lateral aerodynamic moment, lateral damping moment, longitudinal moment of a rocket, lift and drag forces, drag estimation, body upwash and downwash in missiles. Rocket dispersion, re-entry body design considerations

UNIT-lV DYNAMICS & ATTITUDE CONTROL OF ROCKETS & MISSILES

Tsiolskovsky's rocket equation- range in the absence of gravity, vertical motion in the earth's gravitational field, inclined motion, flight path at constant pitch angle, motion in the atmosphere, the gravity turn- the culmination altitude. Multi staging. Earth launch trajectories- vertical segment, the gravity turn, constant pitch trajectory, orbital injection.

Rocket thrust vector control-methods of thrust vector control for solid and liquid propulsion systems, thrust magnitude control, thrust termination; Stage separation dynamics, separation techniques.

UNIT- V ROCKET TESTING

Ground testing and flight testing- types of tests, test facilities and safeguards, monitoring and control of toxic materials, instrumentation and data management. Ground testing, flight testing, trajectory monitoring, post accident procedures. Description of a typical space launch vehicle launches procedure.

TEXT BOOKS

1. Sutton, G.P., and Biblarz, O., *Rocket Propulsion Elements*, 7th edition, Wiley-Interscience, 2000.
2. Cornelisse, J.W., Schoyer H.F.R. and Wakker, K.F., *Rocket Propulsion and Space-flight Dynamics*, Pitman, 1979.
3. Turner, M.J.L., *Rocket and Spacecraft Propulsion*, Springer, 2001.

REFERENCES

1. Chin, S.S., *Missile Configuration Design*, McGraw Hill, 1961.
2. Ball, K.J., Osborne, G.F., *Space Vehicle Dynamics*, Oxford University Press, 1967.
3. Parker, E.R., *Materials for Missiles and Spacecraft*, McGraw Hill, 1982.
4. Mouritz, A. and Bannister, M., *Introduction to Aerospace Materials*, CRC Press, 2010

X. COURSE PLAN:

The course plan is meant as a guideline. There may probably be changes.

Lecture No.	Course Learning Outcomes	Topics to be covered	Reference
1	Explain Basic concepts	**UNIT- I INTRODUCTION** Space launch vehicles and military missiles- function, types, role, mission, mission profile,	R1:1.2
2-3	Discuss the guidance requirements for missile	thrust profile, propulsion system, payload, staging, control and guidance requirements	R1:1.2
4-5	Explain similarities	performance measures, design, construction, operation- similarities and differences	R3:1.3
6	Explain space launch vehicles	Some famous space launch vehicles and strategic missiles	R3:1.5
7-8	Discuss Solid propellant rocket motors	**UNIT-II SOLID & LIQUID PROPELLANT ROCKET MOTOR SYSTEMS** Solid propellant rocket motors, principal features, applications	T1:11.1
9	Discuss Solid propellants	Solid propellants, types, composition, properties, performance.	T1:12.1
10-11	Explain Propellant	Propellant grain, desirable properties, grain configuration, preparation, loading. Structural design of grain. Liners, insulators and inhibitors- function, requirements, materials	T1:11.3
12-13	Explain Rocket motor casing	Rocket motor casing- materials	T1:11.3
14	Explain Nozzles	Nozzles- types, design, construction, thermal protection.	T1:14.3
15-16	Explain Igniters	Igniters, types, construction. Description of modern solid boosters I) Space Shuttle SRB, ii) the Arianne SRB	T1:14.3
17-18	Explain element theories	simple blade element theories	R2:2.3
19-20	Discuss Liquid propellants	Liquid propellants- types, composition, properties, performance. Propellant tanks, feed systems- pressurization, turbo-pumps-valves and feed lines, injectors, starting and ignition	T1:6.1
21-22	Discuss Engine cooling	Engine cooling, support structure. Control of engine starting and thrust build up, system calibration	T1: 6.3
23-24	Analyze integration and optimization	integration and optimization- safety and environmental concerns	T1:7.7

25-26	Discuss Space Shuttle main engine	Description of the Space Shuttle main engine. Propellant slosh, propellant hammer, geysering effect in cryogenic rocket engines	T1:15.1
27	Discuss Airframe components of rockets and missiles	**UNIT-III AERODYNAMICS OF ROCKETS AND MISSILES** Classification of missiles. Airframe components of rockets and missiles	R1:2.2
28-29	Explain Forces acting on a missile	Forces acting on a missile while passing through atmosphere, method of describing aerodynamic forces and moments	R1:3.2
30-31	Discuss lateral aerodynamic moment	lateral aerodynamic moment, lateral damping moment	R1:9.3
32	Describe longitudinal moment of a rocket	Longitudinal moment of a rocket, lift and drag forces, drag estimation,	R1:5.2
33-34	Expalin the reentry design requirements	body upwash and downwash in missiles. Rocket dispersion, re-entry body design considerations	R1:5.2
35-36	Discuss rocket equation	**UNIT-IV DYNAMICS & ATTITUDE CONTROL OF ROCKETS AND MISSILES: T**siolskovsky's rocket equation-range in the absence of ravity, vertical motion in the earth's gravitational field, inclined motion, flight path at constant pitch angle	T2:11.2.1 to 11.2.2
37-38	Analyze motion in the atmosphere	Motion in the atmosphere, the gravity turn- the culmination altitude. Multi staging	T2:11.3.1
39	Discuss launch trajectories	Earth launch trajectories- vertical segment, the gravity turn, constant pitch trajectory, orbital injection.	T2:13.4
40-41	Analyze Actual launch vehicle trajectories	Actual launch vehicle trajectories- types. Examples, the Mu 3- S-II, Ariane, Pegasus launchers. Reusable launch vehicles- future launchers- launch assist technologies	T3:8.4
42-43	Explain vectored thrust	Rocket thrust vector control	T1:16.1
44-46	Discuss Performances of VTOL aircraft in hover	methods of thrust vector control for solid and liquid propulsion systems, thrust magnitude control, thrust termination	T1:16.2
47-48	Analyze Stage separation dynamics	Stage separation dynamics, separation techniques	T1:16.4
49-50	Discuss Ground testing	**UNIT- V ROCKET TESTING:** Ground testing and flight testing	T1: 20.
51	Discuss types of tests	types of tests, test facilities and safeguards,	T1:20.2
52	Discuss about the toxic materials	monitoring and control of toxic materials	
53	Discuss instrumentation	Instrumentation and data management. Ground testing, flight testing	T1:20.3
54	Decribe the post accident Procedures	Trajectory monitoring, post accident procedures	T1:20.3
55	Discuss typical space launch vehicle launch procedure	Description of a typical space launch vehicle launch procedure	T1:20.3

XI. MAPPING COURSE OBJECTIVES LEADING TO THE ACHIEVEMENT OF THE PROGRAM OUTCOMES

Course Objectives	Program Outcomes												Program Specific Outcomes			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
I	H			H	S		H		S		H		S		H	
II																
III		S			S			S			S			H		
IV				H												
V	H					H			H			S				

S = Supportive **H = Highly related**

XII. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF THE PROGRAM OUTCOMES

Course Outcomes	Program Outcomes												Program Specific Outcomes			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
1			S		H				S			H		S		
2																
3			H										S		S	
4	S				S		H			S						
5								S								
6	H												H		H	
7					H					H				S		
8	S		H								S					
9								H			H			H		
10	H			H												
11												S				
12		H			S				H							

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Prepared by: Mr. Shiva Prasad U, Assistant Professor

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