Country	Institution	Module Description	ECTS
PRT	**PrAFA**	**Propulsion Systems**	**2**

Service	Minimum Qualification for Lecturers
AF	• **Officers**: ○ English: Common European Framework of Reference for Languages (CEFR) Level B2 or NATO STANAG Level 3. ○ Thorough knowledge in Propulsion Systems ○ Adequate knowledge in Thermodynamics and heat exchange ○ Adequate knowledge in Principles of Flight and Aerodynamics ○ Adequate knowledge in Military Aviation
Language **English**	• **Civilian Lecturers:** ○ English: Common European Framework of Reference for Languages (CEFR) Level B2 or NATO STANAG Level 3. ○ Thorough knowledge in Propulsion Systems ○ Adequate knowledge in Thermodynamics and heat exchange ○ Adequate knowledge in Principles of Flight and Aerodynamics ○ Adequate knowledge in Military Aviation

Prerequisites for international participants:	**Goal of the Module**
• English: Common European Framework of Reference for Languages (CEFR) Level B1 or NATO STANAG Level 2. • At least 1 year of national (military) higher education.	• To broaden the knowledge on Propulsion Systems for Aircraft, especially for Air Breathing Internal Combustion and Gas Turbine Engines • To gain sufficient insight to comprehend the working principles of the engine types mostly used in aviation • To acquire knowledge and understand the thermodynamic principles of air breading combustion engines • To identify different types of engines, engine components, accessories used in aviation • To engage in a multi-national course where all students are expected to bring their knowledge and contribution to the lectures and teaching sessions

Learning outcomes		
	Know-ledge	• To foster the interest of young cadets in the topics of propulsion, fluid dynamics and thermodynamics; • To gain technical knowledge on Internal Combustion engine and Gas Turbine engine mechanical and thermodynamic principles; • To acquire in-depth knowledge on the main factors affecting powerplant design and selection for different types of aircraft; • To understand and identify the main pros and cons on each engine type and configuration, depending on the type of application;
	Skills	Technical • To understand and apprehend the working principles of internal combustion and jet/turbo engines; • To identify different types of engines, engine components and accessories;

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		• To identify the main technical design variables that influence the selection of a powerplant design feature and powerplant selection for a specific type of aircraft; • To understand the main limitations of current engines and propellers; Transversal • Develop a multi-cultural awareness; • Improve team spirit, in heterogeneous, multi-cultural environment; • To improve English language level and skills; • To develop communication skills;
	Responsibility & Autonomy	• To considerably increase independence and autonomy in solving problems; • To grow and foster transnational cooperation spirit, engaging in multi-national classes and projects; • To develop the student's sense of responsibility and understanding of foreign nation's AFA's rules, culture and history;

Verification of Learning Outcomes	
Observation	• The lecturer is responsible for the in-class observation of the Learning Outcomes detailed above, especially, on the items related with Knowledge and Skills; • The lecturer should promote excel in-class environment and enough ease and proximity with the students to allow them to participate, ask questions and share experiences; • The lecturer will promote the participation of all students, equally, and assess their interest, responses and dedication;
Test	• A 1-hour exam will be provided at the end of the course. All questions will have a multiple answer decision sheet;
Assignment	• The class will be divided in groups. Each group will be given a topic to develop and present in-class. Presentation should be less than 1 hour in total, for each group.
Case study	• N/A

Module Details		
Main Topic	**Recom-mended WH**	**Details**
Internal Combustion (IC) Introduction and Thermodyna mic Principles	3	• Introduction to Piston Engines: Thermodynamic notions, Compression Ratio, Otto cycle, Power, Torque, Specific Fuel Consumption;
IC Engine Lubrication, Cooling and Ignition	2	• Lubrication system: Brief description, main components (Oil Tank, Suction Filter, The Pressure Pump, The Check Valve, Scavenge Pump, Oil Cooler, Lubrication Monitoring Instruments), , Types and properties of lubricants; • Engine cooling system: Brief description, main system types (Liquid and Air Cooling systems), • Engine ignition system: Brief description (magneto and dual), main components (capacitor, ground wire, auxiliary starting devices, venting);
IC Fuel, Mixture, Carburettors, Icing, Fuel Injection	3	• Air/fuel mixture (actual and stoichiometric), air/fuel excess ratio (λ_α). • Air/fuel mixture preparation systems: Brief description (Garburator, Injection), main components (Fuel Pumps, manifold valve, air control unit, discharge nozzle), Carburettor icing and relevant actions to be taken, engine slow running and starting, power enrichment, accelerator pump, engine priming • Combustion process in Otto engine: Flame kernel, flame propagation rate, combustion rate, type of fuel, ignition timing. • Abnormal combustion process: Knocking, detonation its causes and effects, anti-detonation properties, fuel additives, pre-ignition, effect on engine performance characteristics. • ; •
IC Performance, Supercharge and propellers	2	• Engine Performance: Brake power/torque/BSFC vs air density, altitude, engine operation point (load, engine speed) • Supercharging systems: Brief description, system types, main components (Centrifugal compressor, wastegate, drive); • Propeller analysis: Components and characteristics, fixed pitch, variable pitch, alpha and beta range, CSP, PCU, Synchronizing;
Gas Turbine Engine (GTE) Introduction, Principles and types of engines	3	• Introduction to GTE: Joule cycle, Power, Specific Fuel Consumption. • Working principles, Main engine types (Turbojet, Turbofan, Turboprop, Turboshaft.) Main engine layouts (single and multispool engines); • Gas turbine performance: Thrust/Inlet momentum drag/TSFC vs altitude, airspeed, ambient conditions;
GTE Inlets and Compressors	3	• Air Inlets, main performance aspects. • Compressor: Brief description, main types (centrifugal, axial flow).

		• Unstable compressor operation mode (stall, surge), and methods to prevent it (variable stator vanes, bleed valves, multispool design)
GTE Combustion Chambers and Turbine Assembly	3	• Combustion chamber: Brief description (Primary air, secondary air flows), main types (annular, can-annular, can) and components (fuel drain, airspray, vaporizers). • Combustion chamber performance: pressure loss, efficiency; • Turbine: brief description, main types (radial, axial flow), main design aspects (blade loading, number of stages, blade materials, blade shape, blade fixing) • Turbine performance: temperature profile, and power losses;
GTE Exhaust and Lubrication	2	• Exhaust systems: Brief description in case of mixed and unmixed flow engines, main components (nozzle -convergent-divergent-, jet pipe, noise suppression), danger areas in the vicinity of an engine and aircraft with engine on; • Lubrication systems: Brief description, main components (oil tank, oil pump, magnetic chip, filters, oils);
GTE Thrust, Reverse and Gearboxes	1	• Thrust reversal systems: Brief description, main types (reverse, external, clamshell, bucket, blocker doors); • Gearboxes and accessories;
Revision and extra time for discussions	2	• Overhaul of the course, with highlight of most important knowledge items • Buffer Lecture for discussions, presentations and clarifications on the subjects
Test	1	• Module examination
Subtotal WH	**25**	
Self-Study Hours		
Internal Combustion (IC) Introduction	3	• Introduction to Piston Engines: Thermodynamic notions, Compression Ratio, Otto cycle, Power, Torque, Specific Fuel Consumption;
IC Engine Lubrication, Cooling and Ignition	3	• Lubrication system: Brief description, main components (Oil Tank, Suction Filter, The Pressure Pump, The Check Valve, Scavenge Pump, Oil Cooler, Lubrication Monitoring Instruments), , Types and properties of lubricants; • Engine cooling system: Brief description, main system types (Liquid and Air Cooling systems), • Engine ignition system: Brief description (magneto and dual), main components (capacitor, ground wire, auxiliary starting devices, venting); • Preparation of lecture summary study notes; • Preparation of presentation on topic (1 group at a time)
IC Fuel, Mixture, Carburettors, Icing, Fuel Injection	3	• Air/fuel mixture (actual and stoichiometric), air/fuel excess ratio (λ_α). • Air/fuel mixture preparation systems: Brief description (Garburator, Injection), main components (Fuel Pumps, manifold valve, air control unit, discharge nozzle), Carburettor icing and relevant actions to be

		taken, engine slow running and starting, power enrichment, accelerator pump, engine priming • Combustion process in Otto engine: Flame kernel, flame propagation rate, combustion rate, type of fuel, ignition timing. • Abnormal combustion process: Knocking, detonation its causes and effects, anti-detonation properties, fuel additives, pre-ignition, effect on engine performance characteristics. • Preparation of lecture summary study notes; • Preparation of presentation on topic (1 group at a time)
IC Performance, Supercharge and propellers	3	• Engine Performance: Brake power/torque/BSFC vs air density, altitude, engine operation point (load, engine speed) • Supercharging systems: Brief description, system types, main components (Centrifugal compressor, wastegate, drive); • Propeller analysis: Components and characteristics, fixed pitch, variable pitch, alpha and beta range, CSP, PCU, Synchronizing; Preparation of lecture summary study notes; • Preparation of presentation on topic (1 group at a time)
Gas Turbine Engine (GTE) Introduction, Principles and types of engines	4	• Introduction to GTE: Joule cycle, Power, Specific Fuel Consumption. • Working principles, Main engine types (Turbojet, Turbofan, Turboprop, Turboshaft.) Main engine layouts (single and multispool engines); • Gas turbine performance: Thrust/Inlet momentum drag/TSFC vs altitude, airspeed, ambient conditions;
GTE Inlets and Compressors	3	• Air Inlets, main performance aspects. • Compressor: Brief description, main types (centrifugal, axial flow). • Unstable compressor operation mode (stall, surge), and methods to prevent it (variable stator vanes, bleed valves, multispool design) Preparation of lecture summary study notes; • Preparation of presentation on topic (1 group at a time)
GTE Combustion Chambers and Turbine Assembly	3	• Combustion chamber: Brief description (Primary air, secondary air flows), main types (annular, can-annular, can) and components (fuel drain, airspray, vaporizers). • Combustion chamber performance: pressure loss, efficiency; • Turbine: brief description, main types (radial, axial flow), main design aspects (blade loading, number of stages, blade materials, blade shape, blade fixing) • Turbine performance: temperature profile, and power losses; • Preparation of lecture summary study notes; • Preparation of presentation on topic (1 group at a time)
GTE Exhaust and Lubrication	3	• Exhaust systems: Brief description in case of mixed and unmixed flow engines, main components (nozzle -convergent-divergent-, jet pipe, noise suppression), danger areas in the vicinity of an engine and aircraft with engine on; • Lubrication systems: Brief description, main components (oil tank, oil pump, magnetic chip, filters, oils); • Preparation of lecture summary study notes; • Preparation of presentation on topic (1 group at a time)

GTE Thrust, Reverse and Gearboxes	2	• Thrust reversal systems: Brief description, main types (reverse, external, clamshell, bucket, blocker doors); • Gearboxes and accessories; • Preparation of lecture summary study notes; • Preparation of presentation on topic (1 group at a time)
Studying for final examination	3	• Studying for final examination;
Subtotal WH	**30**	
Total WH	**55**	

List of Abbreviations:

AF ..... Air Force
BSFC ..... Brake Specific Fuel Consumption
CEFR ..... Common European Framework of Reference for Languages
CSP ..... Constant Speed Propeller
ECTS ..... European Credit Transfer and Accumulation System
GTE ..... Gas Turbine Engine
IC ..... Internal Combustion
NATO ..... North Atlantic Treaty Organisation
PCU ..... Power Control Unit
STANAG ..... Standardization Agreement
SFC ..... Specific Fuel Consumption´
TSFC ..... Thrust Specific Fuel Consumption

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